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Kato

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[54] **PICTURE SIGNAL ENCODING METHOD AND APPARATUS AND SIGNAL RECORDING MEDIUM**

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[73] Assignee: **Sony Corporation**, Tokyo, Japan

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[30] **Foreign Application Priority Data**

Dec. 3, 1996 [JP] Japan 8-323157

[51] **Int. Cl.**[7] **H04N 7/12**

[52] **U.S. Cl.** **375/240.03**; 348/419.1

[58] **Field of Search** 348/405, 406, 348/419, 406.1, 419.1, 400.1; 382/251, 252; 375/243, 245, 240.03; 341/200

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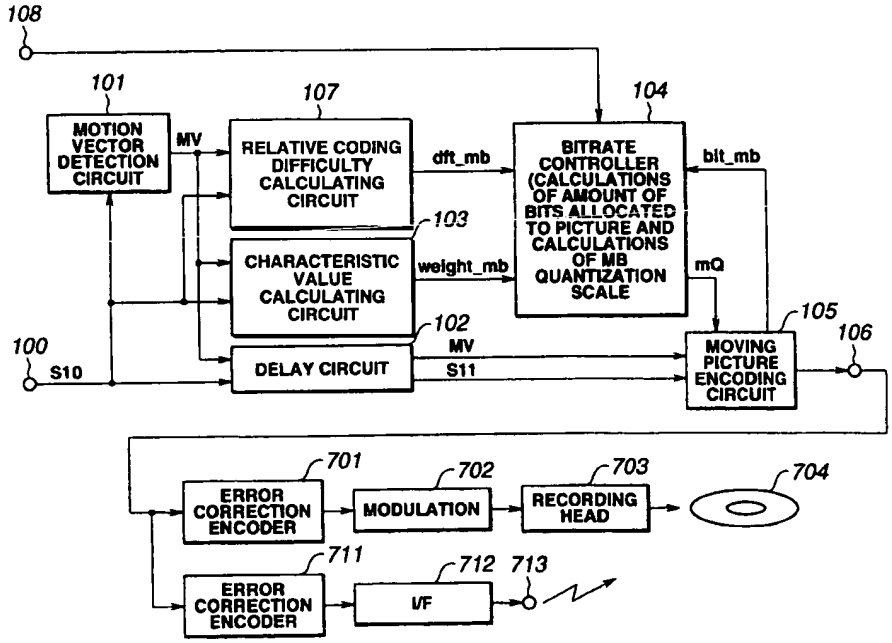
Primary Examiner—Vu Le

Attorney, Agent, or Firm—Limbach & Limbach L.L.P.; Seong-Kun Oh

[57] **ABSTRACT**

A picture signal encoding apparatus on which, even if a picture is not uniform in picture pattern, the picture can be rendered substantially uniform in picture quality, the volume of bits occupying a virtual buffer is stabilized, deterioration in picture quality is rendered less visible and in which stable rate control is assured. The picture signal encoding apparatus, dividing a picture making up moving picture signals into plural macro-blocks MB and encoding the signals from one macro-block to another, includes a relative coding difficulty calculating circuit for calculating the relative coding difficulty from one macro-block to another MB, and a characteristic value calculating circuit for calculating the weighting coefficients (characteristic values) specifying visibility degree of picture quality deterioration from one macro-block MB to another. The picture signal encoding apparatus also includes a bit rate controller for calculating the quantization scale for encoding each macro-block MB using the complexity degree and the volume of allocated bits for macro-block-based encoding.

51 Claims, 15 Drawing Sheets



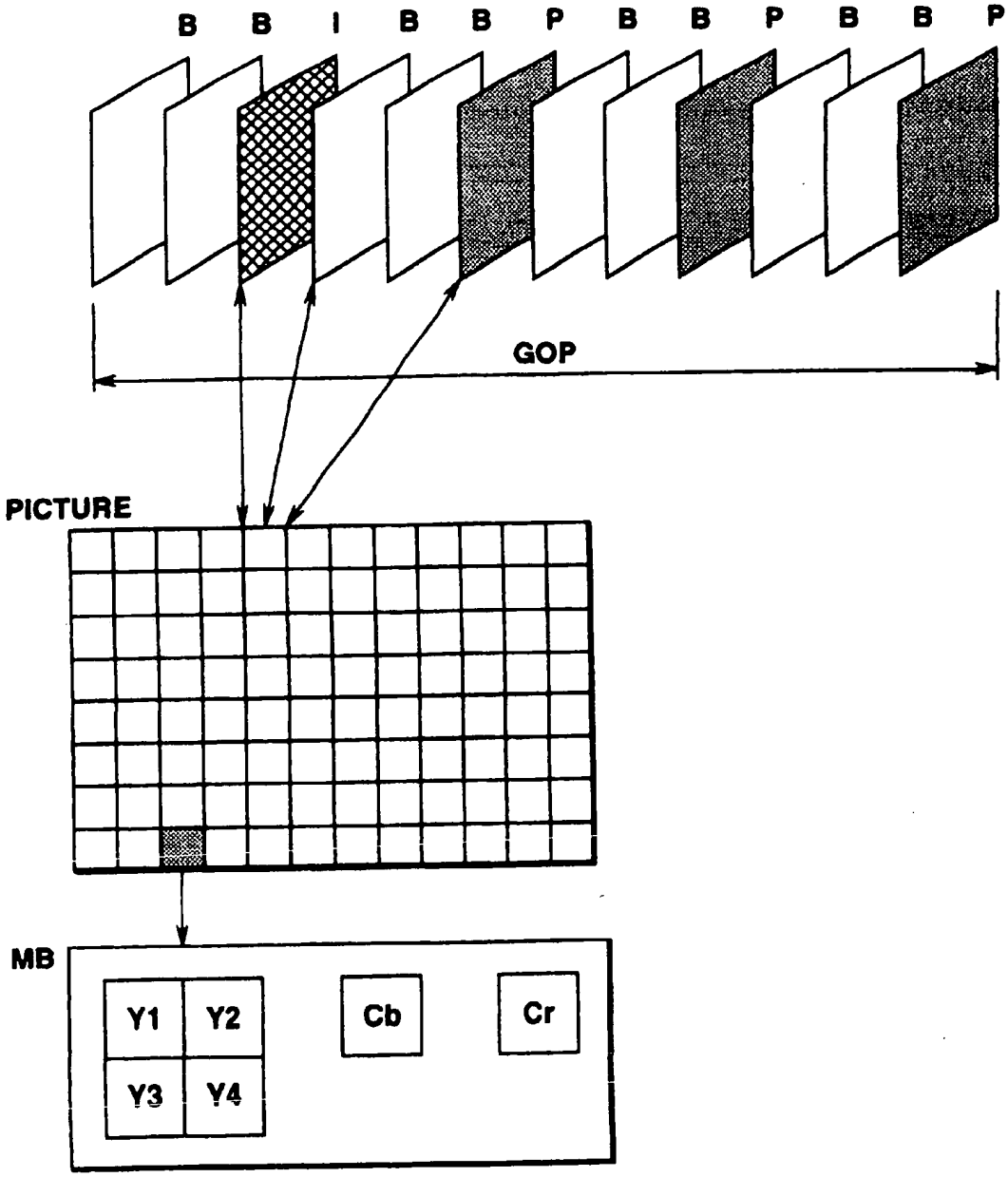


FIG.1
(PRIOR ART)

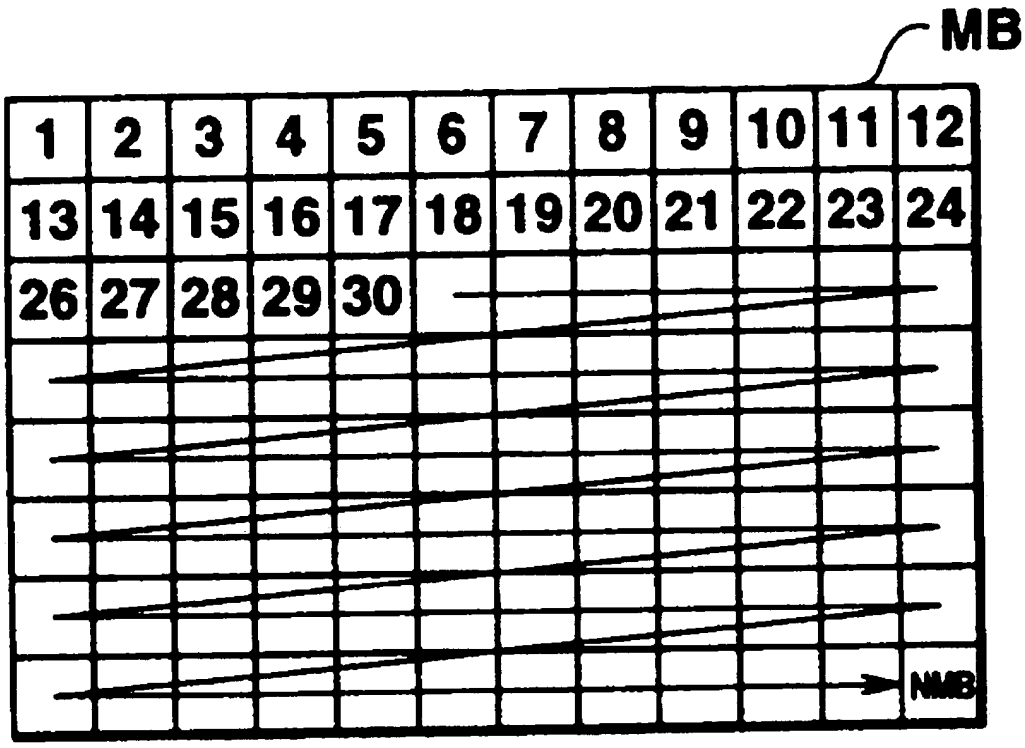


FIG.2
(PRIOR ART)

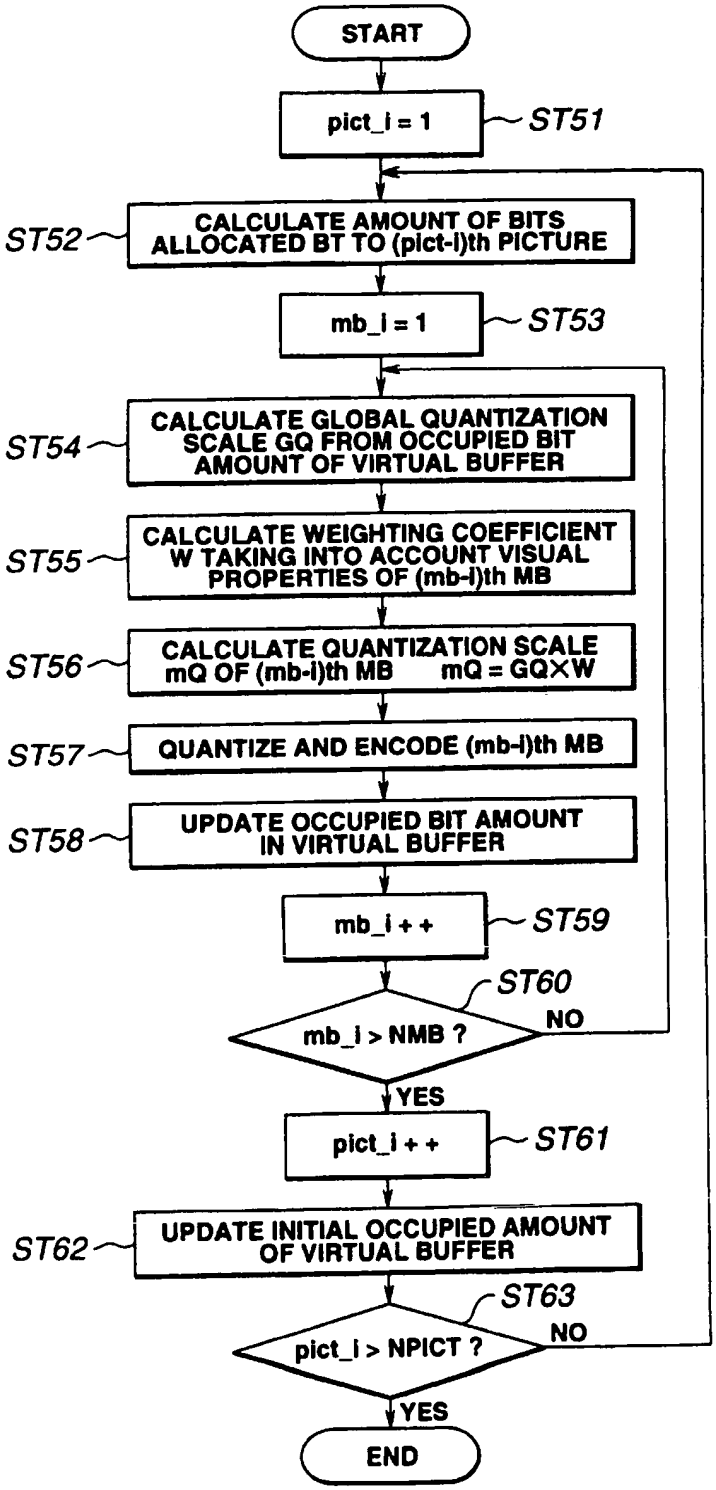


FIG.3
(PRIOR ART)

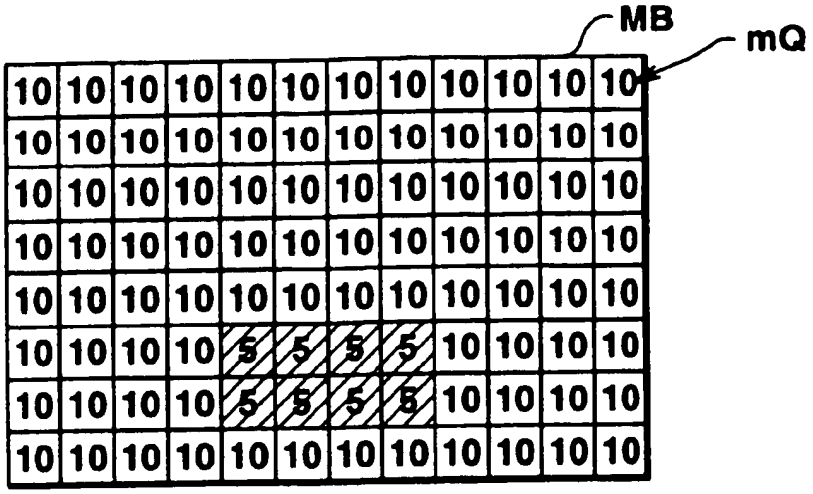


FIG.4A
(PRIOR ART)

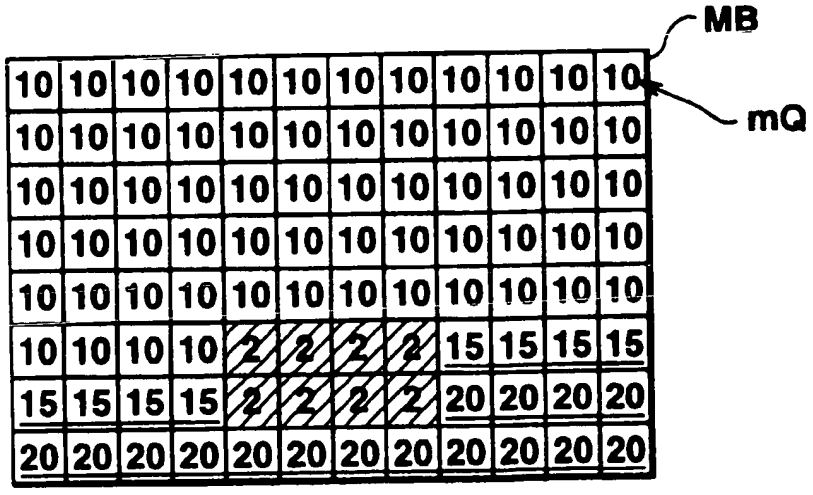


FIG.4B
(PRIOR ART)

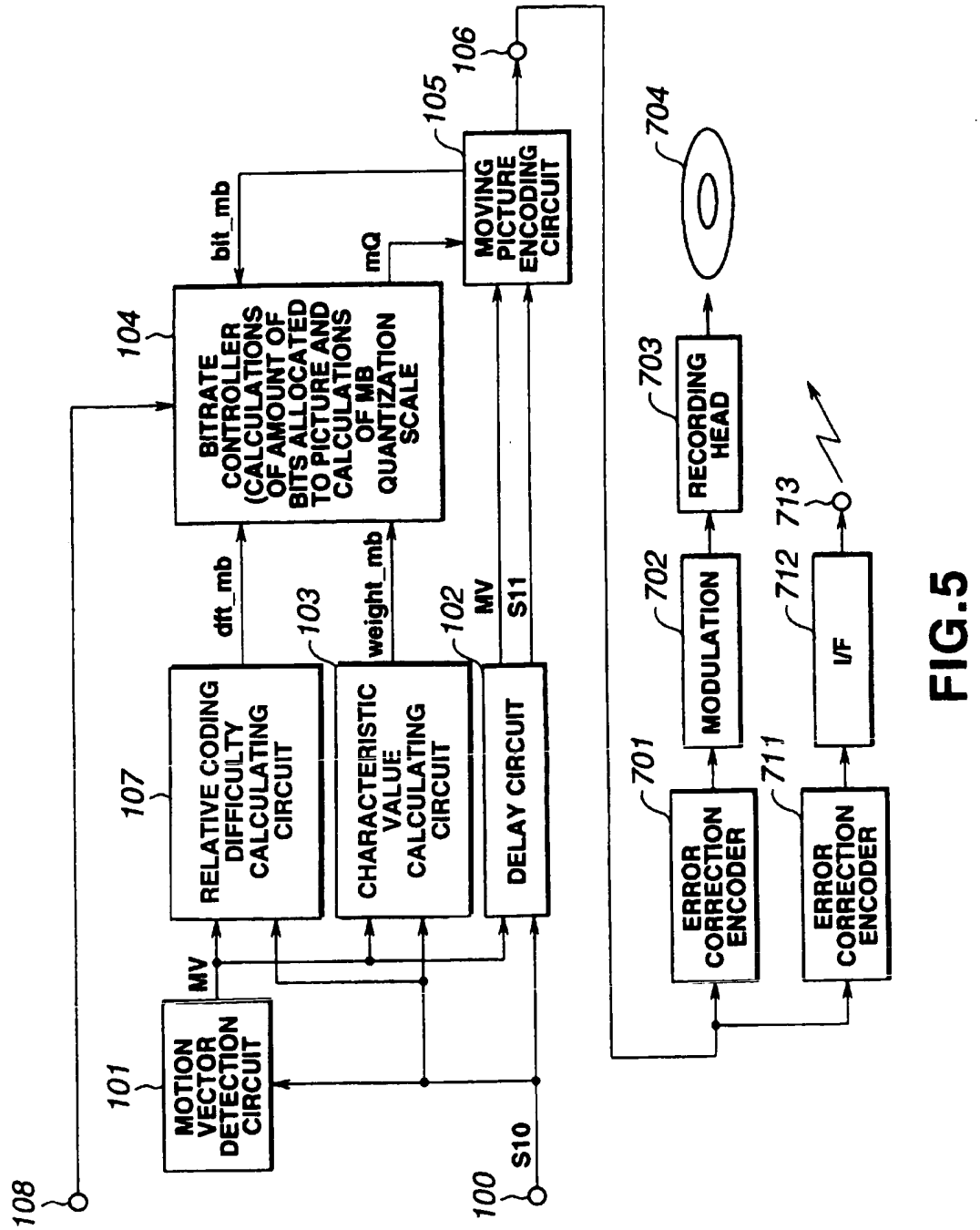

MOTION VECTOR DETECTION CIRCUIT
RELATIVE CODING DIFFICULTY CALCULATING CIRCUIT
CHARACTERISTIC VALUE CALCULATING CIRCUIT
DELAY CIRCUIT
BITRATE CONTROLLER (CALCULATIONS OF AMOUNT OF BITS ALLOCATED TO PICTURE AND CALCULATIONS OF MB QUANTIZATION SCALE
MOVING PICTURE ENCODING CIRCUIT
ERROR CORRECTION ENCODER
ERROR CORRECTION ENCODER
MODULATION
I/F
RECORDING HEAD
MV
dft_mb
weight_mb
MV
S11
bit_mb
mQ
S10
101
103
102
107
104
105
106
701
711
702
712
703
704
713
100
108

FIG.5

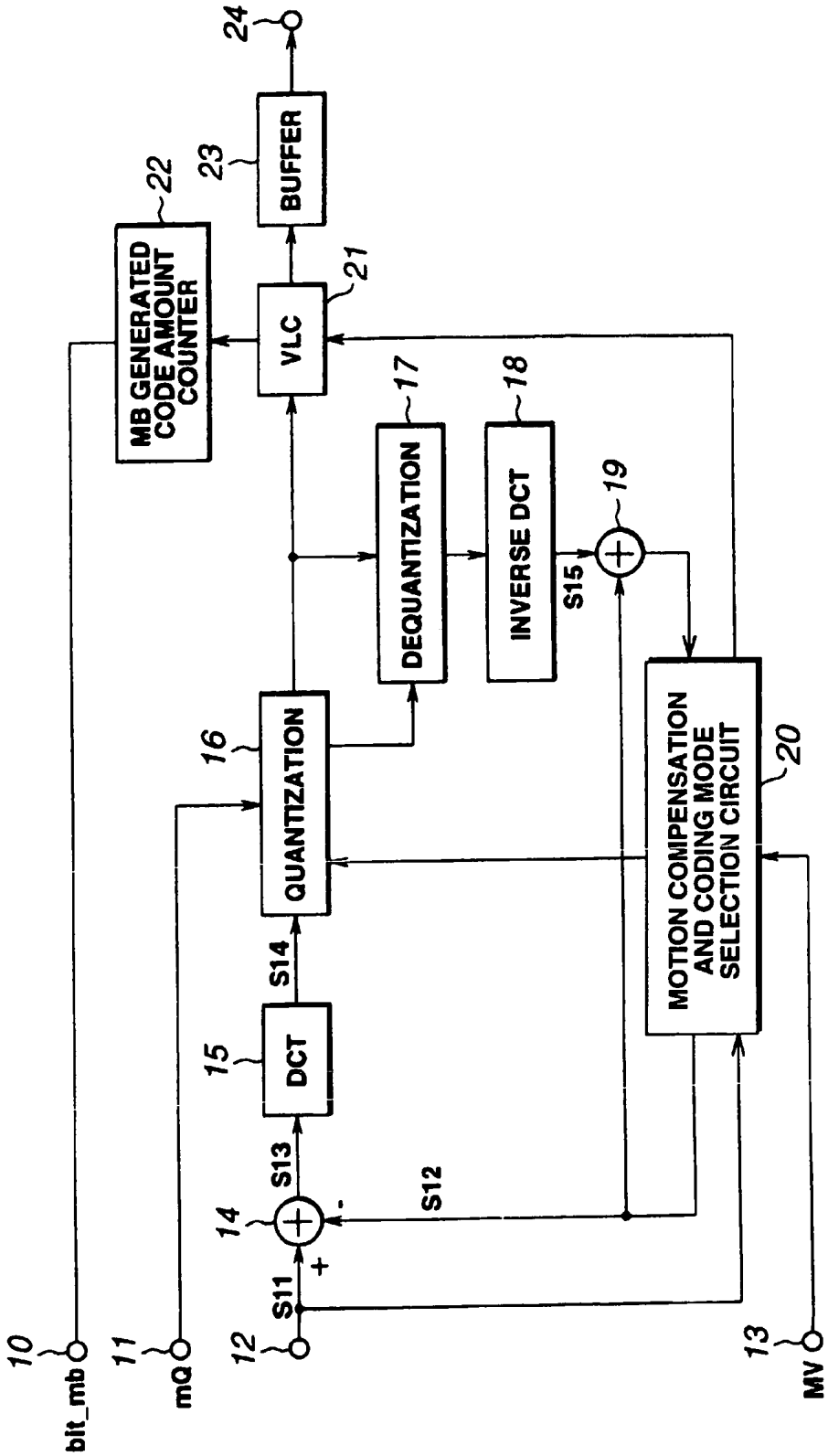

24
BUFFER
23
22
MB GENERATED CODE AMOUNT COUNTER
VLC
21
17
DEQUANTIZATION
18
INVERSE DCT
19
S15
16
QUANTIZATION
20
MOTION COMPENSATION AND CODING MODE SELECTION CIRCUIT
S14
15
DCT
S13
S12
14
S11
10
bit_mb
11
mQ
12
13
MV

FIG.6

QUANTIZATION MATRIX
FOR INTRA-CODING

```
m1 [u, v] = {
 8, 16, 19, 22, 26, 27, 29, 34,
16, 16, 22, 24, 27, 29, 34, 37,
19, 22, 26, 27, 29, 34, 34, 38,
22, 22, 26, 27, 29, 34, 37, 40,
22, 26, 27, 29, 32, 35, 40, 48,
25, 27, 29, 32, 35, 40, 48, 58,
26, 27, 29, 34, 38, 46, 56, 69,
27, 29, 35, 38, 46, 56, 69, 83 } :
```

FIG.7A

QUANTIZATION MATRIX
FOR INTER-CODING

```
m2 [u, v] = {
16, 16, 16, 16, 16, 16, 16, 16,
16, 16, 16, 16, 16, 16, 16, 16,
16, 16, 16, 16, 16, 16, 16, 16,
16, 16, 16, 16, 16, 16, 16, 16,
16, 16, 16, 16, 16, 16, 16, 16,
16, 16, 16, 16, 16, 16, 16, 16,
16, 16, 16, 16, 16, 16, 16, 16,
16, 16, 16, 16, 16, 16, 16, 16 } :
```

FIG.7B

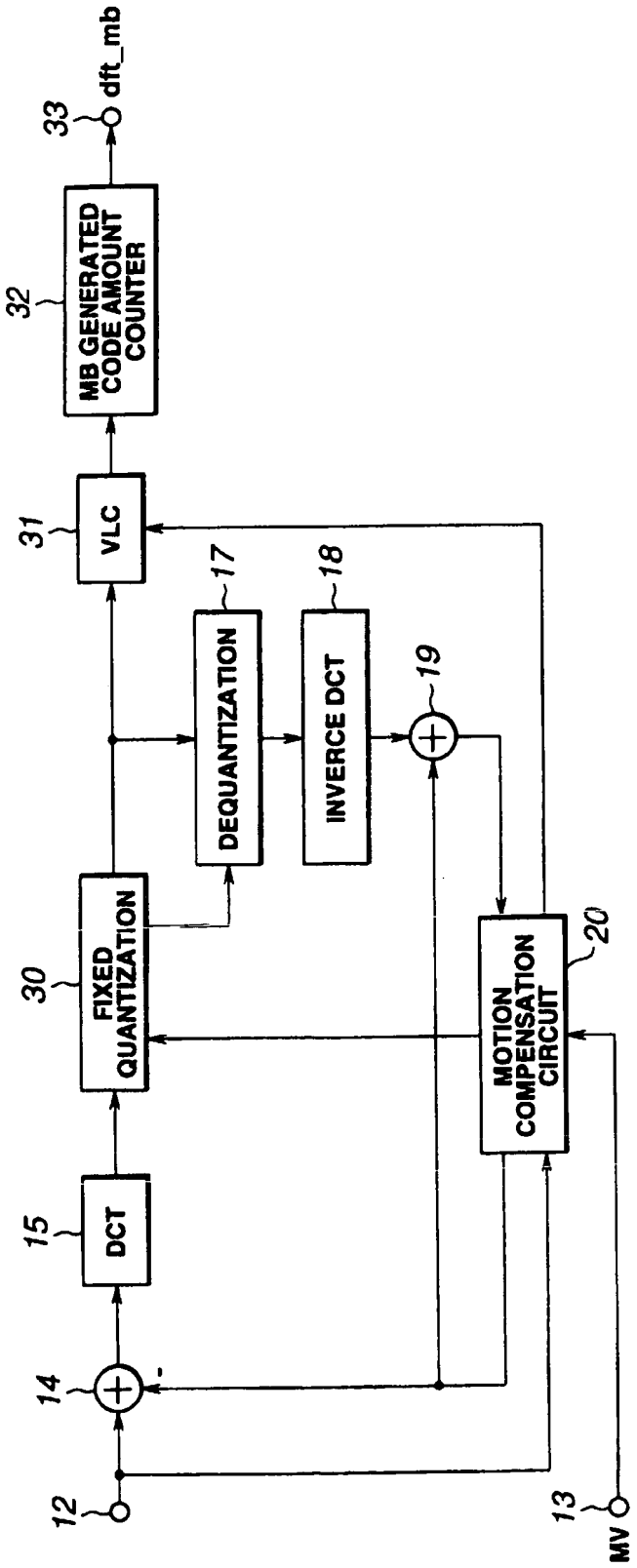

dft_mb
33
MB GENERATED CODE AMOUNT COUNTER
32
VLC
31
17
DEQUANTIZATION
18
INVERCE DCT
19
FIXED QUANTIZATION
30
MOTION COMPENSATION CIRCUIT
20
DCT
15
14
12
13
MV

FIG.8

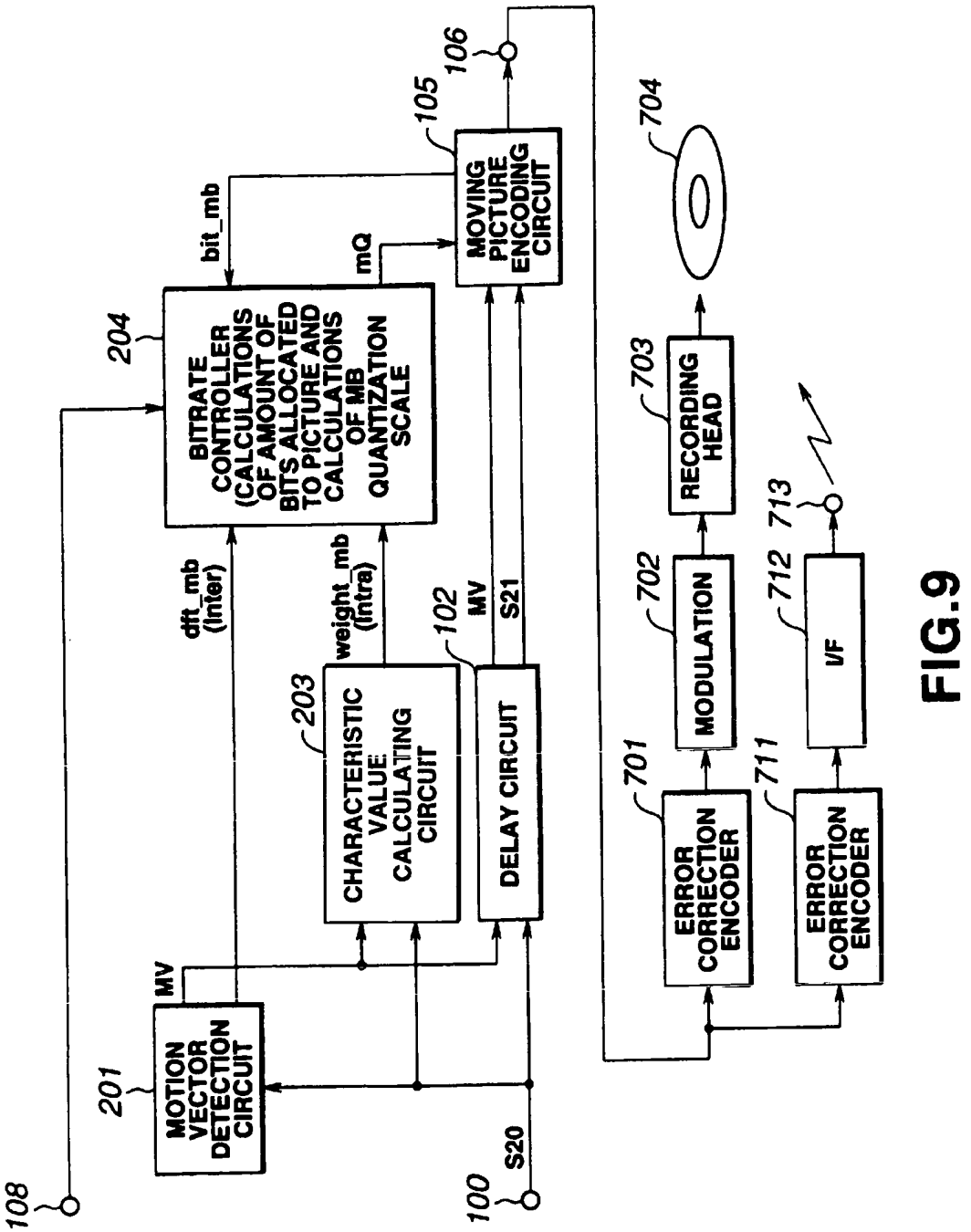

108
100
S20
201
MOTION VECTOR DETECTION CIRCUIT
MV
203
CHARACTERISTIC VALUE CALCULATING CIRCUIT
102
DELAY CIRCUIT
MV
S21
dft_mb (inter)
weight_mb (intra)
204
BITRATE CONTROLLER (CALCULATIONS OF AMOUNT OF BITS ALLOCATED TO PICTURE AND CALCULATIONS OF MB QUANTIZATION SCALE
bit_mb
mQ
105
MOVING PICTURE ENCODING CIRCUIT
106
701
ERROR CORRECTION ENCODER
702
MODULATION
703
RECORDING HEAD
704
711
ERROR CORRECTION ENCODER
712
I/F
713

FIG.9

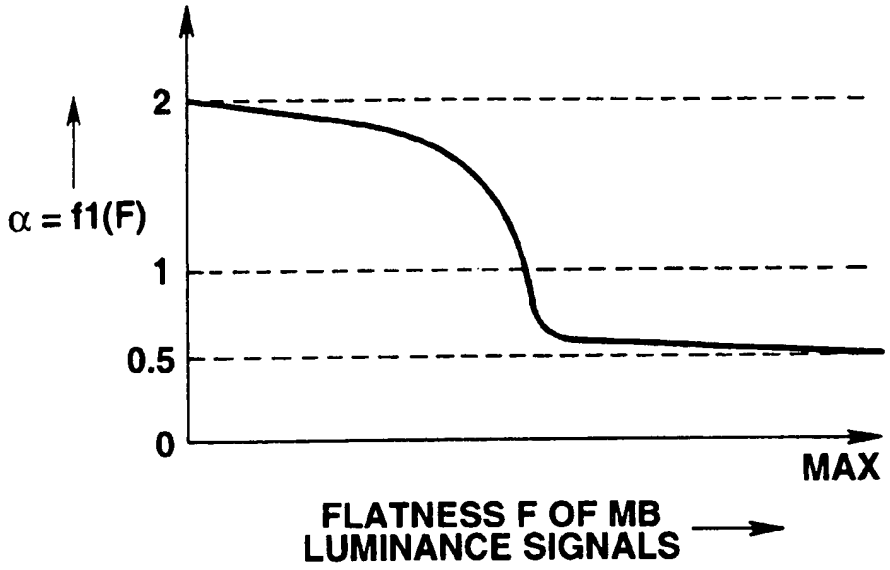

2
α = f1(F)
1
0.5
0
MAX
FLATNESS F OF MB
LUMINANCE SIGNALS

FIG.10

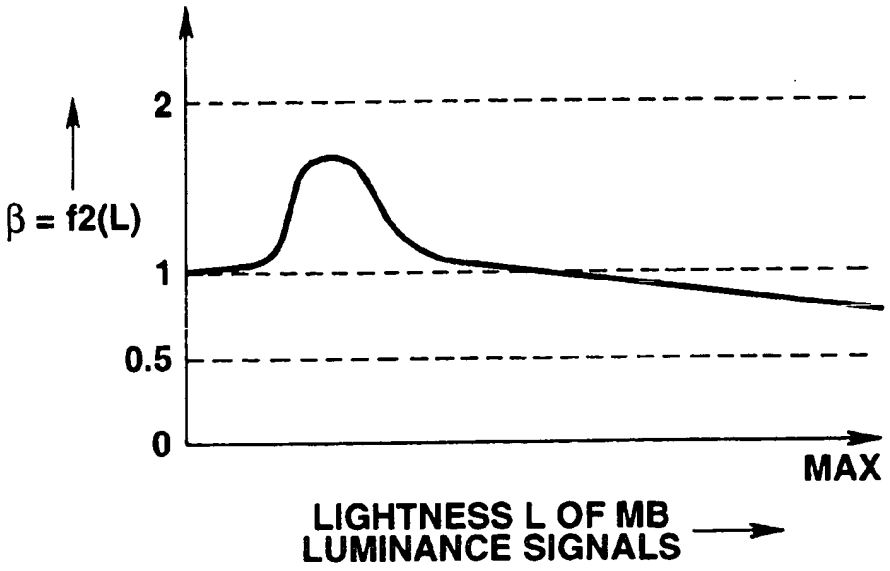

2
β = f2(L)
1
0.5
0
MAX
LIGHTNESS L OF MB
LUMINANCE SIGNALS

FIG.11

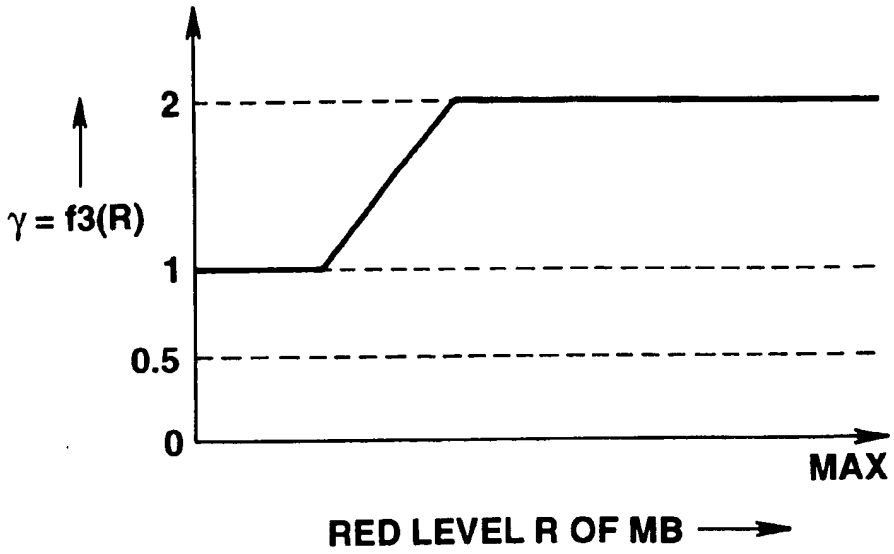

2
γ = f3(R)
1
0.5
0
MAX
RED LEVEL R OF MB

FIG.12

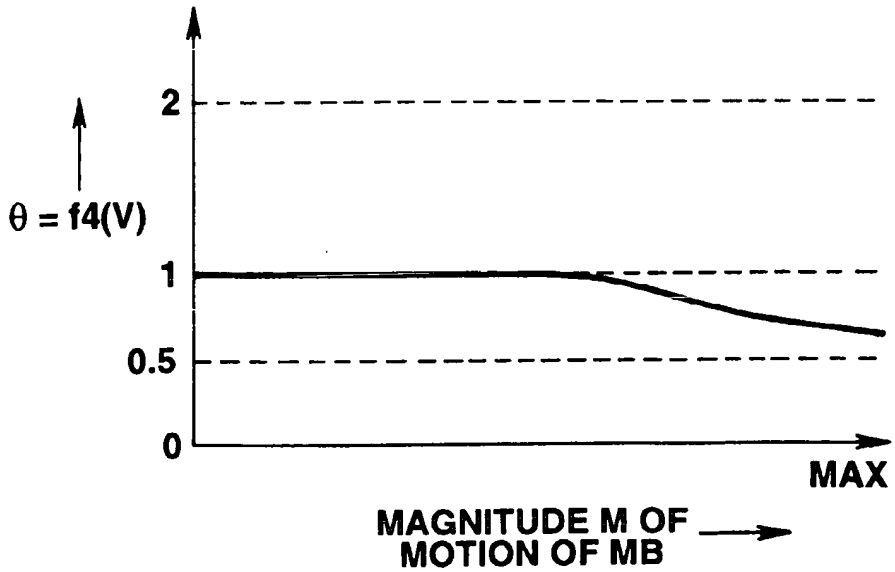
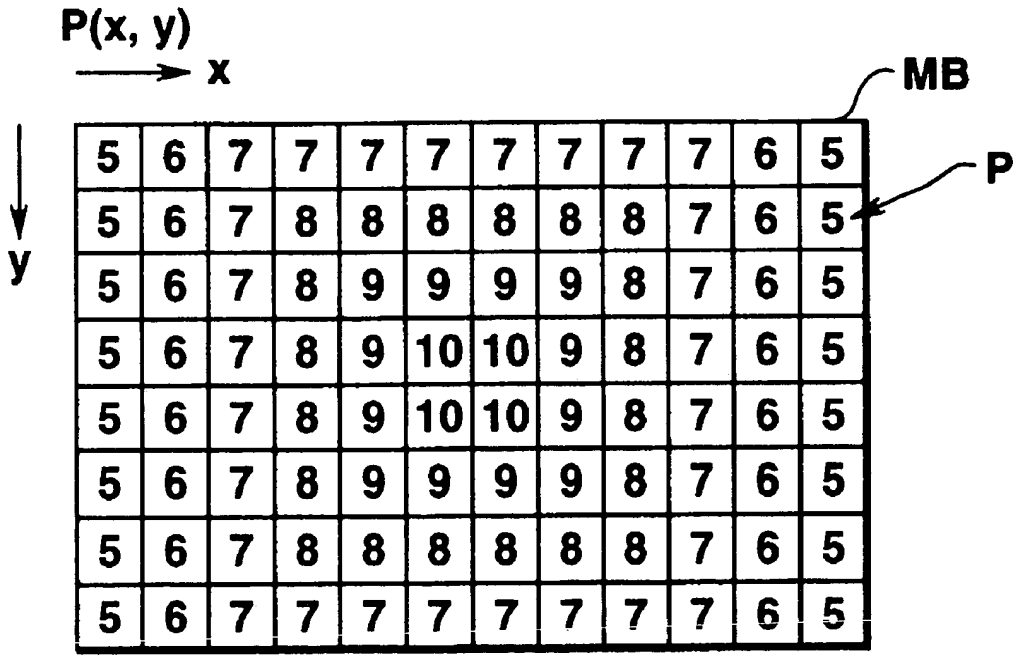

2
θ = f4(V)
1
0.5
0
MAX
MAGNITUDE M OF MOTION OF MB

FIG.13



$\varepsilon = f5(P) = P(x, y) / 10$

FIG.14

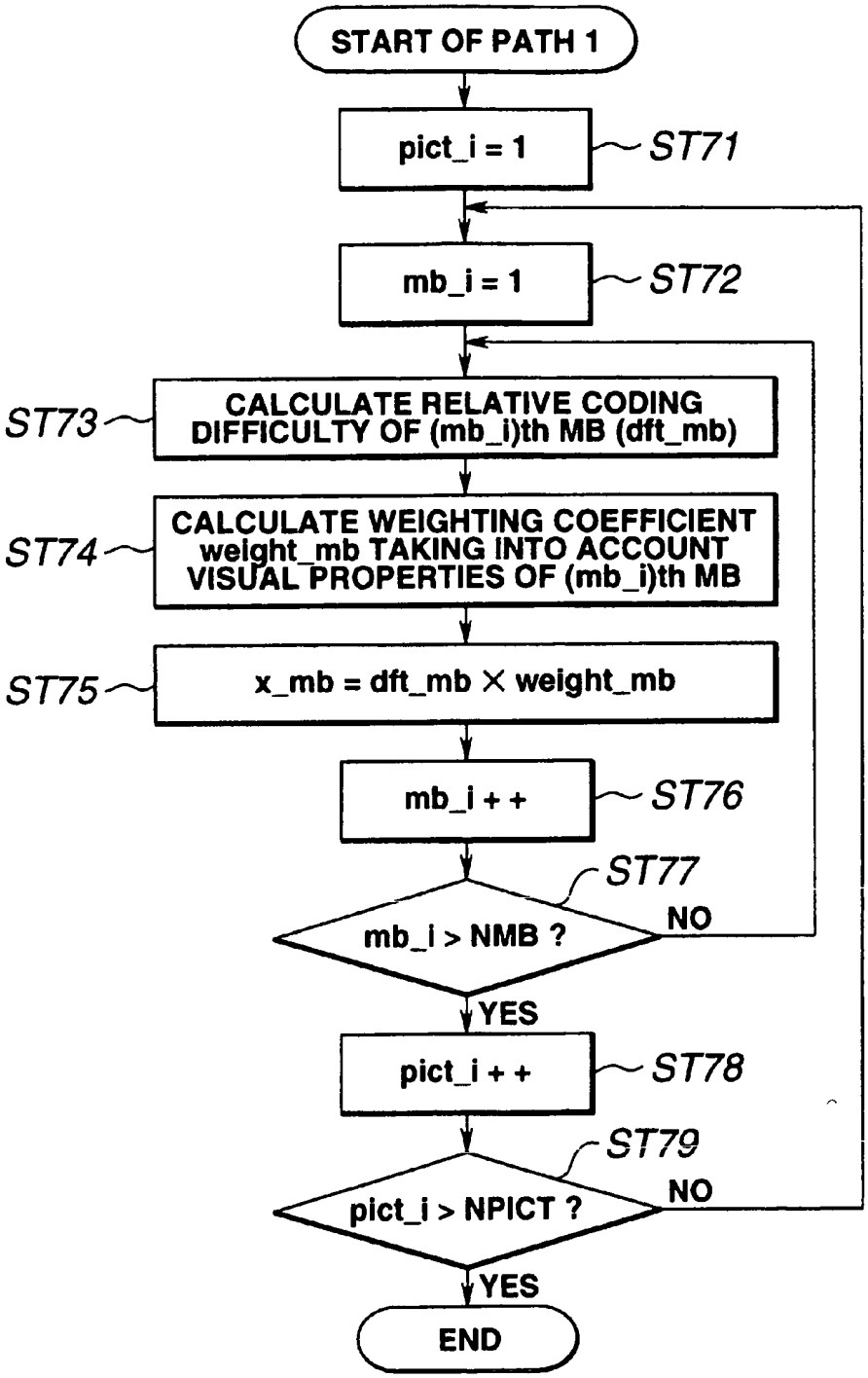

START OF PATH 1
pict_i = 1
ST71
mb_i = 1
ST72
ST73
CALCULATE RELATIVE CODING DIFFICULTY OF (mb_i)th MB (dft_mb)
ST74
CALCULATE WEIGHTING COEFFICIENT weight_mb TAKING INTO ACCOUNT VISUAL PROPERTIES OF (mb_i)th MB
ST75
x_mb = dft_mb × weight_mb
mb_i + +
ST76
ST77
mb_i > NMB ?
NO
YES
pict_i + +
ST78
ST79
pict_i > NPICT ?
NO
YES
END

FIG.15

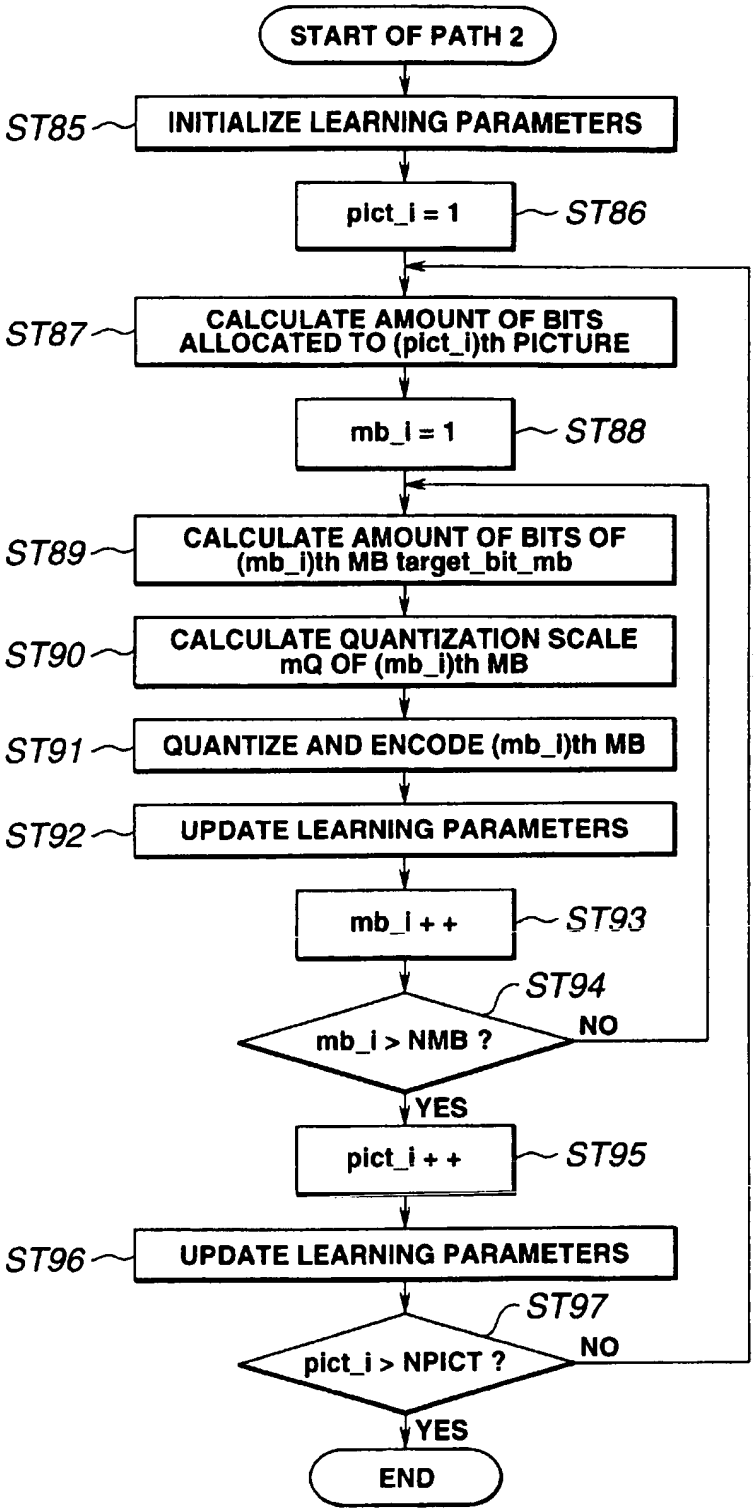

START OF PATH 2
ST85
INITIALIZE LEARNING PARAMETERS
pict_i = 1
ST86
ST87
CALCULATE AMOUNT OF BITS ALLOCATED TO (pict_i)th PICTURE
mb_i = 1
ST88
ST89
CALCULATE AMOUNT OF BITS OF (mb_i)th MB target_bit_mb
ST90
CALCULATE QUANTIZATION SCALE mQ OF (mb_i)th MB
ST91
QUANTIZE AND ENCODE (mb_i)th MB
ST92
UPDATE LEARNING PARAMETERS
mb_i + +
ST93
ST94
mb_i > NMB ?
NO
YES
pict_i + +
ST95
ST96
UPDATE LEARNING PARAMETERS
ST97
pict_i > NPICT ?
NO
YES
END

FIG.16

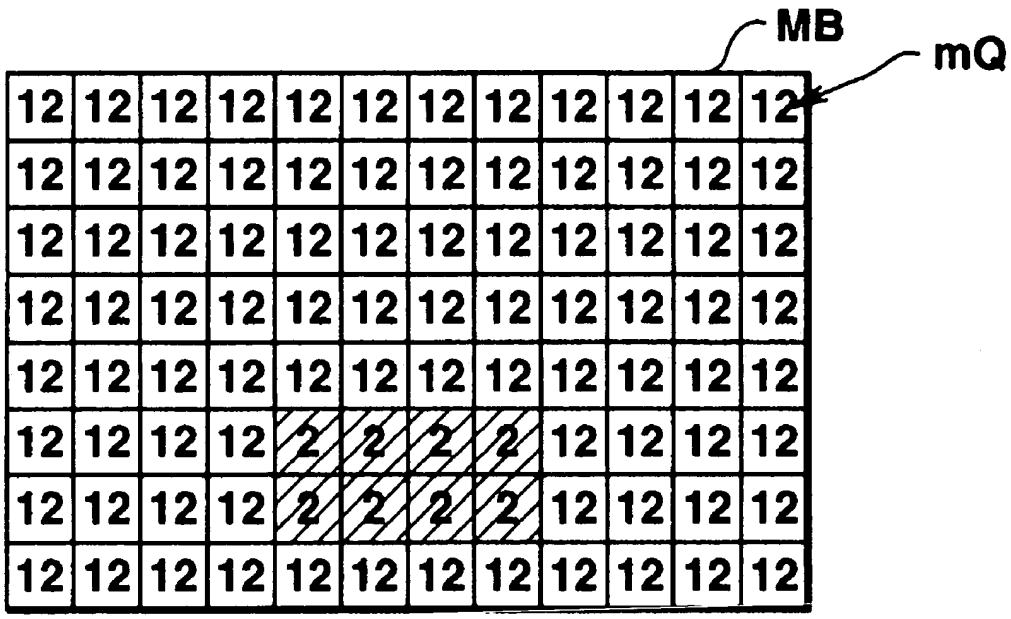

MB
mQ
12 12 12 12 12 12 12 12 12 12 12 12
12 12 12 12 12 12 12 12 12 12 12 12
12 12 12 12 12 12 12 12 12 12 12 12
12 12 12 12 12 12 12 12 12 12 12 12
12 12 12 12 12 12 12 12 12 12 12 12
12 12 12 12 2 2 2 2 12 12 12 12
12 12 12 12 2 2 2 2 12 12 12 12
12 12 12 12 12 12 12 12 12 12 12 12

FIG.17

PICTURE SIGNAL ENCODING METHOD AND APPARATUS AND SIGNAL RECORDING MEDIUM

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a picture signal encoding method or apparatus used in a system for encoding picture signals for moving pictures for storage on a recording medium, such as an optical disc, a magnetic disc or a magnetic tape or in a system for transmitting picture signals of moving pictures over a transmission route. This invention also relates to a signal recording medium used in these systems.

2. Description of Related Art

In general, digital video signals are extremely large in information volume. Therefore, if it is attempted to record the digital video signals for prolonged time on a small-sized recording medium with a small storage information volume (storage capacity), or to transmit the digital video signals over a transmission channel of limited communication capacity, it is indispensable to encode the digital video signals by high efficiency encoding in order to reduce the information volume. For meeting this demand, there are proposed high efficiency encoding systems exploiting the correlation of video signals. One of these systems is the Moving Picture Exerts Group (MPEG) system, in which the inter-frame difference is taken of video signals to lower redundancy along time axis and subsequently the orthogonal transform technique such as discrete cosine transform (DCT) is used to lower redundancy along the spatial axis for efficiently encoding the video signals.

With the MPEG system, the pictures making up a moving picture are classified into three sorts of pictures, namely I-pictures, P-picture or B-pictures, for compression coding of picture signals, as shown in FIG. 1. The I-picture is an intra-coded picture and is decoded independently of other pictures. The P-picture is a forward predictive coded picture obtained on prediction coding from the temporally backward or past I- or P-pictures. The B-picture is a bi-directional predictive coded picture obtained on predictive coding from forward, backward or bi-directional pictures using a temporally forward or backward I- or P-picture. A set of these pictures constitutes so-called group-of-pictures (GOP).

Each picture is divided into smaller units termed macro-blocks. In the case of, for example, a 4:2:0 format digital video, each macro-block MB is made up of six blocks, namely four luminance blocks (Y) and two spatially associated chrominance blocks Cb and Cr. Each of these blocks is made up of 8 by 8 pixels, totaling at 64 pixels.

If the number of pixels in the horizontal direction of the luminance signals is PH, the number MBH of the macro-blocks of a picture in the horizontal direction is given by the following equation (1):

$$MBH=(PH+15)/16 \quad (1)$$

On the other hand, if the number of pixels in the vertical direction of the luminance signals is PV, the number MBV in the vertical direction of a picture of an interlaced frame (with a flag defined by MPEG2 progressive_sequence=0) is given by the following equation (2):

$$MBV=2*((PV+31)/32) \quad (2)$$

The number NMB in a picture is found from the following equation (3):

$$NMB=MBH*MBV \quad (3)$$

FIG. **2** shows the coding sequence of each macro-block MB in an I-picture. That is, the macro-blocks MB in the I-picture are encoded sequentially (in the order specified by numerical figures entered in FIG. **2**) beginning from the first or upper left macro-block up to the NMBth macro-block MB, as shown in FIG. **2**.

In the MPEG coding system, the numbers of allocated bits are preferably varied adaptively from picture to picture for taking advantage of the performance of the three sorts of pictures (I- P- or B-pictures) of different properties. Also, in the MPEG coding system, the quantization scale for quantization of DCT coefficients of a macro-block MB can be varied from one macro-block MB to another for performing bit rate control so that the volume of generated bits of a coded picture will approach a designated amount of allocated bits.

Among widely known systems for controlling the quantization scale of a macro-block MB is a system disclosed in ISO/IEC JTC1/SC29/WG11/N0400 test Model 5, pp. 54 to 57 (April 1993). The corresponding technical information is afforded by, for example, U.S. Pat. No. 5,144,424 entitled APPARATUS FOR VIDEO DATA QUANTIZATION CONTROL. The control system for controlling the quantization scale of this macro-block MB is hereinafter termed TM5 rate control.

FIG. **3** shows a flowchart for this TM5 rate control.

In FIG. **3**, assume that the number of pictures in a video sequence is NPICT and a variable specifying a picture for calculating the volume of allocated bits among the pictures of the sequence is pict_i. That is, the flowchart of FIG. **3** shows the flow for calculation of the volume of allocated bits for the pict-ith one of the pictures in the sequence. The volume of allocated bits for the pict_ith picture is BT. In the following explanation, each variable is described by the C++ language as one of programming languages.

First, at step **ST51**, the variable pict_i is set to 1 as a picture for calculating the volume of allocated bits for specifying the first picture in the sequence.

After this step **ST51**, the above variable pict_i is sequentially incremented by 1 in the processing from step **ST52** to step **ST63** for calculating the volume of allocated bits in each picture in the sequence. The processing from step **ST51** up to step **ST64** is repeated until the calculations of the volume of allocated bits come to a close for all pictures in the sequence.

For this processing from step **ST52** up to step **ST63**, the volume of allocated bits BT for the pict_ith picture is first calculated at step **ST52**. First, parameters specifying picture complexity degree are calculated from one picture type to another, and the volume of allocated bits of the GOP is allotted by proportionate distribution to each picture depending on the picture complexity degree.

At the steps **ST53** and **ST54** to **ST60**, the quantization scale of each macro-block in the pict_ith picture is calculated. Here, the variable specifying the macro-block MB in which the quantization scale is calculated in the pict_ith picture is set as mb_i.

At step **ST53**, of the above steps **ST53** up to **ST60**, the above variable mb_i as the macro-block MB in the pict_ith picture, in which to execute the calculations for the quantization scale, is set to 1 for designating the first macro-block in the picture.

After this step **ST53**, the above variable mb_i is sequentially incremented by 1 in the processing from step **ST54** up

to step ST60, for calculating the quantization scale in each macro-block MB in the picture. The processing from ST54 to step ST60 is repeated until the calculations of the quantization scale for all macro-blocks MB in the picture come to a close.

As the processing from ST54 to step ST60, the total volume of the quantization scale in a picture under consideration is calculated, from the volume of bits occupying the virtual buffer, in accordance with the following equation (4):

$$GQ=d[mb_i]*31/r \quad (4)$$

where GQ is the global quantization scale.

In the above equation, d[mb_i] is the volume of bits occupying the virtual buffer prior to coding of the mb_ith macro-block MB, and r (termed a reaction parameter) is of a constant value pertinent to the target bit rate and the picture rate. The larger the volume of bits occupying the virtual buffer, the larger is the above global quantization scale GQ. Meanwhile, the calculations of the volume of bits occupying the virtual buffer will be explained subsequently in connection with the step ST58.

Next, at step ST55, a weighting coefficient W taking into account the visual characteristics of the mb_ith macro-block MB is calculated from the following equation (5):

$$W=(act[mb_i]+2*avg_act)/(2*act[mb_i]+avg_act) \quad (5)$$

In the equation (5), act[mb_i is a minimum value of the variance of four luminance signal blocks of the macro-block MB. This value specifies picture pattern complexity degree of the luminance signals. The larger this value, the more complex is the picture pattern. In the above equation, avg_act is a mean value of act[mb_i]. In a flat portion where deterioration is perceptually acute, the weighting coefficient becomes larger. Conversely, in a picture portion with complex picture patterns, where deterioration is perceptually less acute, the weighting coefficient W becomes smaller. The weighting coefficient W is normalized so that its value ranges from ½ to 2 and an expected value of W in the I-picture will be equal to 1.

At the next step ST56, the quantization scale mQ of the mb_ith macro-block MB is calculated in accordance with the following equation (6):

$$mQ=GQ/W \quad (6)$$

At the next step ST57, the DCT coefficients of the mb_ith macro-block MB are quantized and encoded for thereby calculating the volume of actually generated bits bit_mb [mb_i] of the mb_ith macro-block MB.

At the next step ST58, the volume of bits occupying the virtual buffer is updated. dI, dP and dB are provided for the I-, P- and B-picture, respectively, and are updated in accordance with the following equations (7) to (9):

$$dI[mb_i+1]=dI[1]+BG[mb_i]-BT*mb_i/NMB \quad (7)$$

$$dP[mb_i+1]=dP[1]+BG[mb_i]-BT*mb_i/NMB \quad (8)$$

$$dB[mb_i+1]=dB[1]+BG[mb_i]-BT*mb_i/NMB \quad (9)$$

In the above equations, dI[1], dP[1] and dB[1] denote the volume of bits initially occupying each virtual buffer and BG[mb_i] denotes the sum of generated encoding bits bit_mb from the first macro-block MB up to the mb_ith macro-block MB of the picture, as shown in the following equation (10):

$$BG[mb_i]=\Sigma bit_mb[mb_i] \ (i=1\sim mb_i) \quad (10)$$

In each of the above equations, (BT*mb_i/NMB) denotes a value obtained on allocating the volume of bits BT allocated to a given picture to mb_i macro-blocks MB among the total number of macro-blocks NMB of the picture.

At step ST59, the address of the macro-block MB is advanced by one. That is, the above variable mb_i is incremented.

At the next step ST60, it is judged whether or not processing of the last macro-block of the pict_ith picture has come to a close, that is whether or not the variable mb_i is larger than the number of macro-blocks NMB in the picture. If the result is negative, that is if processing is not terminated, processing reverts to step ST54. If the result is affirmative, that is if processing has been terminated, processing transfers to the next step ST61.

At this step ST61, the variable pict_i is incremented by 1 before proceeding to processing the next picture.

At step ST62, the volume of bits occupying the virtual buffers dI[NMB+1], dP[NMB+1] and dB[NMB+1] at the time of end of the above-described picture encoding are substituted for the volume of bits occupying the virtual buffers dI[1], dP[1] and dB[1]. That is, the initial volumes of the occupying bits of the virtual buffers are updated as shown by the equations (11) to (13):

$$dI[1]=dI[NMB+1] \quad (11)$$

$$dP[1]=dP[NMB+1] \quad (12)$$

$$dB[1]=dB[NMB+1] \quad (13)$$

At the next step ST63, it is judged whether or not processing of the last picture of the sequence (with the number of pictures of NPICT) has come to a close. Specifically, it is judged whether or not the variable pict_i is larger than the number of pictures NPICT of the sequence. If the result of judgment is negative, that is if processing has not come to a close, processing reverts to step ST52 and, if otherwise, that is if processing has come to a close, processing of TM5 rate control comes to a close.

Meanwhile, when calculating the quantization scale of the current macro-block MB in the above TM5 rate control, the quantization scale GQ is calculated from the current volume of bits occupying the virtual buffer as shown by the above equation (4). The global quantization scale GQ is calculated for stabilizing the volume of bits occupying the virtual buffer calculated by the above equations (7) to (9). That is, feedback is applied such that, if the volume of generated bits of the pictures up to now BG is smaller than the volume of bits allocated up to now (BT*mb_i/NMB) such that the volume of bits occupying the virtual buffer is decreased (that is decreased in value), the global quantization scale GQ is diminished from the equation (4) whereby the volume of generated bits of the macro-block MB is increased to stabilize the volume of bits occupying the virtual buffers. If reverse is the case, that is if the volume of bits occupying the virtual buffer is increased in its value, there is applied such feedback that the global quantization scale GQ is increased to diminish the volume of generated bits of the macro-block MB to stabilize the volume of bits occupying the virtual buffers. This feedback control assures uniform volume of bits generated in the pictures.

However, this control raises a problem if the picture is not uniform in pattern, for example, if the picture contents differ in the upper and lower halves, such that the upper half is of a simple picture pattern whereas the lower half is complex in picture pattern. That is, since feedback is applied such that

the volume of generated bits in the upper half will be equal to that in the lower half, the upper half picture is quantized finely, while the lower picture half is quantized roughly, with the result that the picture quality is not uniform. There is also raised a problem that when the macro-block MB transfers from the upper half picture to the lower half picture, the volume of bits occupying the virtual buffers tends to be non-stable.

Moreover, in the above TM5 rate control, the weighting coefficients taking into account the visual characteristics of the macro-blocks MB are calculated from the flatness of the luminance signals. This, however, is insufficient if desired to render deterioration in picture quality less acute.

In addition, in the TM5 rate control, stable rate control is not assured if the weighting coefficients W are not normalized so that the expected value in the I-picture of the weighting coefficients W taking into account the visual characteristics will be equal to 1. For example, assume that the quantization scale mQ indicated by numerical figures in FIG. **4** has been calculated in each macro-block MB, wherein smaller and larger values of the numerical figures stand for fine quantization and rough quantization, respectively. Also assume that, in this case, it is desired to reduce the quantization scale of the macro-blocks shown shaded in FIG. **4A**, and the weighting coefficients only of the macro-blocks shown shaded in FIG. **4A** are increased. Since the expected value of the weighting coefficients ceases to be equal to 1, only the quantization scale calculated for the macro-blocks following the macro-blocks shown shaded in FIG. **4B** is increased.

In the TM5 rate control, since the weighting coefficients W for flatness of the macro-blocks MB are normalized relative to an average value of the flatness of the I-picture in calculations, the expected value of the weighting coefficients W is 1. However, if the weighting coefficients W are absolutely designated for the parameters taking into account visual characteristics of the macro-block MB, such that the expected value of the weighting coefficients W ceases to be 1, stable rate control is not assured.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a picture signal encoding method and apparatus and a signal recording medium in which a picture having non-uniform pattern can be rendered substantially constant in picture quality, the volume of bits occupying a virtual buffer can be stabilized, picture quality deterioration can be rendered less acute and in which the stable rate control is assured.

In one aspect, the present invention provides a method for encoding picture signals in which moving picture signals are divided into plural domains for encoding from one domain to another, including calculating relative coding difficulty from domain to domain, calculating weighting coefficients representing the degree of visibility of picture quality deterioration from domain to domain, calculating the complexity degree from domain to domain, based on the relative coding difficulty and the weighting coefficients and calculating the quantization scale for encoding for the domains based on the complexity degree and the allocated bit volumes for encoding the domains.

In calculating the quantization scale, the volume of bits allocated to each domain is calculated in proportion to the complexity degree of each domain relative to complexity of the entire picture. The relative coding difficulty is calculated using the volume of codes generated on encoding each domain with a fixed quantization scale, the volume of predicted remainder signals at the time of detecting the motion vector of each domain or the difference residual volume from a mean value of each domain. The weighting coefficients are calculated based on the combination of at least one of the lightness, redness, amount of motion and the position of each domain in the picture, in addition to the flatness of the luminance signals of the moving picture. The encoded data string of the picture obtained on this encoding is transmitted or recorded.

In another aspect, the present invention provides a recording medium having recorded thereon an encoded data string obtained on calculating, for each of plural domains into which is divided a picture making up moving picture signals, the relative coding difficulty and weighting coefficients representing the visibility degree of picture quality deterioration, calculating the complexity degree from the relative coding difficulty and the weighting coefficients, calculating the quantization scale of encoding for each domain based on the volume of allocated bits for encoding each domain and complexity degree and on encoding each domain based on the quantization scale.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates typical results of calculations of a MPEG data structure.

FIG. **2** illustrates the coding sequence of the macro-blocks MB in a picture.

FIG. **3** is a flowchart showing the flow of calculations of the quantization scale of the macro-block MB by TM5 system rate control.

FIGS. **4A** and **4B** illustrate typical results of calculations of the quantization scale of the macro-blocks MB of a picture by a conventional method.

FIG. **5** is a block circuit diagram showing a first embodiment of a picture signal encoding device according to the present invention.

FIG. **6** is a block circuit diagram showing an illustrative structure of a moving picture encoding circuit.

FIGS. **7A** and **7B** illustrate quantization matrices for intra-coding and inter-coding, respectively.

FIG. **8** is a block circuit diagram showing an illustrative structure of an relative coding difficulty calculating circuit.

FIG. **9** is a block circuit diagram showing a second embodiment of a picture signal encoding device according to the present invention.

FIG. **10** is a graph for illustrating a function f1 between coefficients α and flatness F of luminance signals of the macro-block MB.

FIG. **11** is a graph for illustrating a function f2 between coefficients β and lightness L (mean value) of luminance signals of the macro-block MB.

FIG. **12** is a graph for illustrating a function f3 between coefficients γ and redness R of the macro-block MB.

FIG. **13** is a graph for illustrating a function f4 between coefficients θ and the amount of motion M of the macro-block MB.

FIG. **14** is a graph for illustrating a function f5 between coefficients ϵ and a position P of the macro-block MB in a picture.

FIG. **15** is a flowchart showing the flow of calculations for the first path for calculating the first path for calculating the quantization scale of the macro-block MB by bit rate control embodying the invention.

FIG. **16** is a flowchart for illustrating the flow of calculations for the second path in calculating the quantization

scale of the macro-block MB in the bit rate control embodying the invention.

FIG. **17** illustrates typical results of calculations of the quantization scale of the macro-block MB of a picture in the picture signal encoding method of the present invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

Referring to the drawings, preferred embodiments of a picture signals encoding method and apparatus and a signal recording medium according to the present invention will be explained in detail.

FIG. **5** shows a first embodiment of a picture signal encoding device of the present invention.

In FIG. **5** a digital moving picture signal **S10** entering a terminal **100** is sent to a motion vector detection circuit **101** and to a delay circuit **102** as later explained. Since the digital moving picture signal **S10** is processed as from this time from one macro-block MB to another, this signal **S10** is termed input MB signal.

The motion vector detection circuit **101** calculates the motion vector MV on the macro-block basis from the digital moving picture signal **S10**. This motion vector detection is by pattern matching between a reference frame and the current macro-block MB. That is, a sum Ef of absolute values of differences between a signal A[i,j] of the current macro-block signal MB and a signal F[i,j] of a macro-block referred by an optional motion vector:

$$Ef=\Sigma|A[i,j]-F[i,j]|(i=0\ to\ 15, j=0\ to\ 15) \quad (14)$$

The motion vector detection circuit **101** outputs a motion vector which gives the smallest value of Ef as a motion vector signal MV.

The input MB signal **S10** and its macro-block based motion vector MV are sent to a relative coding difficulty calculating circuit **107** where the relative coding difficulty dft_mb of the input MB signal **S10** is calculated. The relative coding difficulty is a parameter specifying the MB-based volume of the input MB signal **S10**. An illustrative structure of the relative coding difficulty calculating circuit **107** will be explained subsequently. The relative coding difficulty dft_mb is sent to a bit rate controller **104**.

The input MB signal **S10** and its macro-block based motion vector MV are sent to a characteristic value calculating circuit **103** where a weighting coefficient weight_mb of the input MB signal taking into account the visual characteristics are calculated. The weighting coefficient weight_mb is a parameter representing the degree of visibility of deterioration due to coding. The characteristic value calculating circuit **103** will be explained subsequently. The weighting coefficient weight_mb is sent to the bit rate controller **104**.

On the other hand, the input MB signal and its macro-block based motion vector MV are delayed by the delay circuit **102**, until the quantization scale mQ of the macro-block MB is outputted by the bit rate controller **104**, before being supplied to a motion vector coding circuit **105**. The digital motion vector signal delayed by the delay circuit **102** is termed hereinafter an input MB signal **S11** for distinction from the input MB signal. The input MB signal **S11** outputted by the delay circuit **102** is encoded by the moving picture encoding circuit **105** to generate a coded bitstream which is outputted at an output terminal **106**. The volume of the encoded generated bits bit_mb, calculated by the moving picture encoding circuit **105**, is sent to the bit rate controller **104** which will be explained in detail subsequently.

FIG. **6** shows an illustrative structure of a moving picture encoding circuit **105**. This moving picture encoding circuit **105** executes hybrid encoding which is a combination of motion-compensated inter-frame prediction and DCT.

In FIG. **6**, the input MB signal **S11** from the delay circuit **102** of FIG. **1** is supplied to a terminal **12**, whilst the macro-block based motion vector MV, delayed by the delay circuit **102**, is supplied to a terminal **13**. The input MB signal **S11** and the associated motion vector MV are entered to a motion compensation circuit **20**.

The motion compensation circuit **20** includes a picture memory from which the macro-block based prediction picture signal MB, referred to hereinafter as prediction MB signal, is read out. The sum of absolute values of the macro-block based difference between the input MB signal and the prediction MB signal is compared to the sum of absolute values of the differences from the mean value of the input MB signal. If the former or the latter is found to be smaller, the inter-coding mode or the intra-coding mode is set, respectively. If the picture is an I-picture, all macro-blocks MB are set to the intra-coding mode. The motion compensation circuit **20** outputs the prediction MB signal as a signal **S12**, if the coding mode is the inter-coding mode, while outputting all-zero signals of the macro-block MB as a signal **S12** if the coding mode is the intra-coding mode.

An arithmetic unit **14** adds the input MB signal **S11** as an addition signal and the above signal **S12** as a subtraction signal from one macro-block to another to find the difference between the input MB signal **S11** and the signal **S12** to output the resulting difference as a predicted remainder MB signal **S13**.

The predicted remainder MB signal **S13** is then sent to a DCT circuit **15** which then performs the 8×8-pixel two-dimensional DCT on the predicted remainder MB signal **S13** on the block basis to output the resulting DCT coefficients **S14**. These DCT coefficients **S14** are sent to a quantization circuit **16**.

The quantization circuit **16** then quantizes the DCT coefficients based on the quantization scale mQ supplied via terminal **11** from the bit rate controller **104** of FIG. **5** and the intra/inter prediction mode determined by the motion compensation circuit **20** in order to quantize the DCT coefficients as follows:

If the mode is the intra-coding mode,

DC coefficients

$$i[0,0]=c[0,0]/8 \quad (15)$$

AC coefficients

$$i[u,v]=16*c[u,v]/(mQ*m1[u,v]) \quad (16)$$

If the mode is the inter-coding mode,

$$i[u,v]=16*c[u,v]/(mQ*m2[u,v]) \quad (17)$$

In the above equations, c[u,v] (u=0 to 7 and v=0 to 7) are input DCT coefficients and i[u,v] are the quantized DCT coefficients. Also, in the above equations, m1[u,v] denotes a quantization matrix for intra-coding and m2[u,v] denotes a quantization matrix for inter-coding. FIGS. **7A**, **7B** show examples of the quantization matrix m1[u,v] for intra-coding and the quantization matrix m2[u,v] for inter-coding, respectively. In the above equations, symbols // and / denote integer division for rounding to the nearest integer and an integer division with rounding off for approaching the result towards 0, respectively.

The quantized output signal of the quantization circuit **16** and the associated motion vector MV are sent to a variable-length encoding circuit (VLC) **21**. The VLC **21** variable-length encodes the quantized output signal and the motion vector MV based on the MPEG syntax.

The signal obtained by this variable length coding is sent to a buffer memory **23**. This buffer memory **23** smoothes variations in the volume of generated bits during a short time period from the VLC **21** to output a coded bitstream of the target bitrate. The coded bitstream outputted by the buffer memory **23** is outputted at a terminal **24** and thence supplied to the output terminal **106** of FIG. **5**.

An output signal of the VLC **21** is also sent to a counter **22** which counts the volume of codes of the output signal of the VLC **21** to find the volume of generated codes corresponding to the input MB signal to transmit the generated code volume as the aforementioned volume of generated encoded bits bit_mb to a terminal **10**. The volume of generated encoded bits bit_mb outputted by this terminal **10** is sent to the bit rate controller **104**.

On the other hand, the quantized output signal and the quantization scale of the quantization circuit **16** are sent to a dequantization circuit **17** which then dequantizes the quantized output signal in association with the above-mentioned quantization scale. An output of the dequantization circuit **17** is supplied to an inverse DCT circuit **18** for inverse DCT and decoding to give prediction remainder MB signal which is entered to an arithmetic unit **10**.

This arithmetic unit **19** is fed with the same signal as the aforementioned prediction MB signal **S15** supplied to the arithmetic unit **14**. The arithmetic unit **19** adds the prediction MB signal **S12** to the prediction MB signal **S15**. This gives a locally decoded picture signal which is the same signal as the output picture on the receiver or decoder side.

FIG. **8** shows an illustrative structure of the relative coding difficulty calculating circuit **107** shown in FIG. **5**. This relative coding difficulty calculating circuit **107** is basically the same as the moving picture encoding circuit explained with reference to FIG. **6**, with the difference being that a fixed quantization scale is used in the quantization circuit **30** and the volume of bits occupied in the buffer is not supervised in connection with the volume of generated codes from the VLC **31**. That is, the volume of generated bits from the VLC **31** is counted up by a counter **32** from one macro-block MB to another such that relative coding difference dft_mb is outputted at a terminal **33**. In FIG. **8**, parts or components similar to those of FIG. **2** are denoted by the same reference numerals and the corresponding description is omitted for simplicity.

FIG. **9** shows a second embodiment of the picture signal encoding device of the present invention.

The present second embodiment of the picture signal encoding device differs from the above-described first embodiment of the picture signal encoding device as to the method of calculating the relative coding difficulty dft_mb of the macro-block MB. In FIG. **6**, parts or components similar to those of FIG. **5** are denoted by the same reference numerals and the corresponding description is omitted for simplicity.

If, in this second embodiment of the picture signal encoding device of FIG. **9**, the input digital moving picture signal (input MB signal) **S20** is encoded as a P- or B-picture, the prediction remainder of the input MB signal **S20** from the motion vector detection circuit **201**, that is the sum Ef of the absolute values of the differences calculated by the above equation (14), is used as the macro-block based relative coding difficulty dft_mb. If the input MB signal **S20** is encoded as an I-picture, the sum of absolute values of the differences from the mean value of the input MB signal **S20** calculated by a characteristic value calculating circuit **203** is used as the macro-block based relative coding difficulty dft_mb. It is also possible to use a variance of the input MB signal **S20** as the relative coding difficulty dft_mb(intra) of the macro-block MB. The bit rate controller **204**, supplied with the relative coding difficulty dft_mb(inter) or dft_mb (intra), will be explained in detail subsequently. The operation other than that described above is the same as that for the picture signals encoding device explained in connection with the first embodiment shown in FIG. **5**. The digital moving picture signal delayed by the delay circuit **102** is indicated as **S21** in FIG. **9**.

The operations of the characteristic value calculating circuit **103** for the macro-block MB in the picture signal encoding device shown in FIG. **5** and the characteristic value calculating circuit **203** for the macro-block MB in the picture signal encoding device shown in FIG. **9** are next explained. These characteristic value calculating circuits calculate, as characteristic values of the input MB signal (**S10** or **S20**), the flatness F, lightness L, redness (red level) R, the amount (magnitude) of motion M and the position of the macro-block MB in the picture.

As the flatness F, the variance values of the luminance signals of the macro-block MB, for example, are calculated.

As the lightness L, a mean value of the luminance signals of the macro-block MB, for example, is calculated.

As the red level (R), the size of the red area in the macro-block MB is calculated. For example, the pixel value Cr[i,j] of the Cr block of the macro-block MB is compared to the pixel value Cb[i,j] of the Circuit board block to calculate the red level R counted by the if-condition of equation (18):

$$if((Cr[i,j]>TH1)\&\&(Cr[i,j]<TH2))R{+}{+};\ (i=0\ to\ 7,\ j=0\ to\ 7) \quad (18)$$

wherein TH1 and TH2 denote constant threshold values. In the above equation (18), described using the so-called C++ language, symbols > and < are relative operators for judging relative magnitude of data, symbols ++ denotes increment operators, R++; means incrementing R by 1 and symbols && denotes a logical operator specifying a logical product.

As the motion value M, the magnitude of the motion vector of the macro-block MB is calculated. The weighting coefficients p are found by the position of the macro-block MB in a picture.

The above-mentioned characteristic value calculating circuit **103** or **203** finds coefficients αi, βi, γi, δi and ϵi, mapping characteristics of the functions f1 to f5 onto weighting coefficients mb_weight[i] specifying the relative visual perceptibility of deterioration in picture quality to find respective weighting coefficients mb_weight[i] by a product of these coefficients:

$$\alpha i=f1(Fi) \quad (19)$$

$$\beta i=f2(Li) \quad (20)$$

$$\gamma i=f3(Ri) \quad (21)$$

$$\theta i=f4(Mi) \quad (22)$$

$$\epsilon i=f5(Pi) \quad (23)$$

$$mb_weight[i]=\alpha i\times\beta i\times\gamma i\times\theta i\times\epsilon i \quad (24)$$

where Fi, Li, Ri, Mi and Pi denote flatness, lightness, red level, amount of motion and weighting coefficient of the positions of the macro-block MB, respectively.

Specified examples of the characteristics of the functions f1 to f5 are explained with reference to FIGS. **10** to **14**.

FIG. **10** shows characteristics of a function f1 describing the relation between the flatness (variance) of luminance signals of the macro-block MB and the function f1 of the coefficients α. In FIG. **10**, the abscissa denotes F with 0 denoting complete flatness and MAX denoting a most random picture pattern. In general, the human eye can recognize the encoding noise in the flat portion of a picture pattern, while it can hardly recognize deterioration in the random pattern portion of the picture. Based on this feature, the coefficient α is increased for lower flatness F and decreased towards higher flatness F.

FIG. **11** shows characteristics of a function f2 specifying the coefficient β against lightness (mean value) L of luminance signals of the macro-block MB. The lightness L on the abscissa of FIG. **11** denotes that 0 and MAX stand for black and the lightest value, respectively. In general, the human eye can easily recognize the encoding noise. In a dark picture for darkness beyond a certain level, however, the encoding noise can hardly be perceived because of excessive darkness. Based on this feature, the coefficient β is set to 1 in the vicinity of lightness L=0. The coefficient β is set to have a peak value at the level of lightness L which most readily permits the deterioration to be perceived, with the coefficient β being gradually decreased for larger values of the lightness L.

FIG. **12** shows characteristics of the relation between the red level R of the macro-block MB and a function f3 of the coefficient γ. The red level R on the abscissa of FIG. **12** equal to 0 and MAX denote that there is no red area and that the entire area of the macro-block MB is of red color, respectively. In general, deterioration in red color is readily perceptible to the human eye. Based on this feature, the coefficients γ is increased for the measure of a red area larger than a pre-set value.

FIG. **13** shows characteristics of the relation between the amount of the motion M of the macro-block MB and a function f4 of the coefficient θ. The amounts of motion M on the abscissa of FIG. **13** equal to 0 and MAX denote a still picture and a picture showing maximum motion (fastest motion), respectively. In general, the human eye cannot follow the motion if a picture has fast motion, such that it can hardly recognize picture deterioration. Based on this feature, the coefficient θ is a small value not larger than 1 for the larger value of the amount of motion M.

FIG. **14** shows characteristics between weighting coefficients P in terms of numerical values specifying the degree of visibility of deterioration and the position of the macro-block MB in the picture. In general, the human being tends to view the center of a picture, while deterioration in picture quality at picture edge portions is visible to a lesser extent. Based on this feature, the weighting coefficients are decreased radially from the picture center. The coefficients ε are calculated from the following equation (26):

$$\epsilon = P[x,y]/10 \tag{25}$$

The characteristic value calculating circuit **103** or **203** multiplies the coefficients α, β, γ, θ and ε thus found by one another to find weighting coefficients weight_mb of the macro-block MB. As for the ith macro-block MB, the coefficients αi, βi, γi, θi and εi are found and multiplied by one another as shown in the equation (24) to give the weighting coefficients weight_mb of the ith macro-block MB. For calculating these weighting coefficients weight_mb, one or more of the coefficients αi, βi, γi, θi and εi may also be used instead of using all of these coefficients.

The processing flow for calculating the relative coding difficulty dft_mb and the weighting coefficients weight_mb of the macro-block MB and determining the quantization scale of the macro-block MB by the bit rate controller **104** or **204** is hereinafter explained. The bit rate control carried out by the bit rate controller **104** or **204** is of two paths. FIGS. **15** and **16** show the operation of the first and second paths, respectively.

The operation of the first path shown in FIG. **15** is aimed at searching the complexity degree x_mb of the macro-block MB of the input moving picture signal.

At step ST**71** of FIG. **15**, the variable pict_i is set to 1 for designating the first picture in the sequence as being a picture processed for the first path. This designates the initial picture among the pictures of the sequence.

After this step ST**71**, the variable pict_i is incremented each time processing goes through the steps ST**72** to ST**79** for processing each picture in the sequence by the first-path processing. The processing from this step ST**72** to step ST**79** is repeated until the first-path processing of each macro-block of all pictures in the sequence comes to a close.

In the first step ST**72** of the processing from step ST**72** to step ST**79**, the above variable mb_i is set to 1 as the macro-block MB processed by the first path processing in the pct_ith picture for designating the first macro-block MB in the picture.

After this step ST**72**, the above variable mb_1 is incremented each time the processing goes through the steps ST**73** to ST**77** for processing the macro-blocks MB in the picture for all macro-blocks MB in the picture. This processing from step ST**73** up to step ST**77** is repeated until the first-path processing for all macro-blocks in the picture comes to a close.

As the processing from step ST**73** up to step ST**77**, the relative coding difficulty dft_mb of the mb_ith macro-block is calculated as described above.

At the next step ST**74**, the weighting coefficients weight_mb, specifying the relative visibility of picture quality deterioration taking into account the visual characteristics of the mb_ith macro-block MB, are calculated as explained previously.

At the next step ST**75**, the relative complexity degree x_mb of the mb_ith macro-block MB is calculated by multiplying the relative coding difficulty dft_mb of the macro-block with the weighting coefficients weight_mb, as shown by the equation (26):

$$xmb[mb_i] = dft_mb_i] * weight[mb_i] \tag{26}$$

At the next step ST**76**, the address of the macro-block MB is advanced by one. That is, the above variable mb_i is incremented by one.

At the step ST**77**, it is judged whether or not the processing of the last macro-block MB of the pict_ith picture has come to a close. If it is judged at this step ST**77** that the processing has not come to a close, processing reverts to step ST**73**. If it is judged at this step ST**77** that the processing has come to a close, processing transfers to processing of the next picture.

At step ST**79**, it is judged whether or not processing of the last picture of the sequence (with the number of pictures being NPCT) has come to a close. If it is judged at this step ST**79** that the processing has not come to a close, processing reverts to step ST**72**. If it is judged at this step ST**79** that the processing has come to a close, processing transfers to step ST**80** to terminate the first path processing.

The second path processing shown in FIG. **16** is aimed at calculating the quantization scale mQ of the macro-block MB of the input moving picture signal.

At first step ST85 of FIG. 16, the learning parameter KQ is initialized. The initial value KQ[1] of the learning parameter KQ is pertinent to the calculating conditions of the relative coding difficulty of the macro-block. The learning parameter KQ is updated at the subsequent step ST92.

At the next step ST86, the above variable pict_i is incremented for specifying the first picture among the pictures in the sequence as a picture processed by the second path processing.

After this step ST86, the above variable pict_1 is incremented each time the processing goes through the steps ST87 to ST97 for processing the macro-blocks MB in the picture for all macro-blocks MB in the picture. This processing from step ST87 up to step ST97 is repeated until the second-path processing for all macro-blocks in the picture comes to a close.

At the first step ST87 in the processing from the step ST87 up to step ST97, the volume of allocated bits BT of the pict_ith picture is calculated. That is, in the bit rate controller 104 or 204, the volume of the allocated bits of the GOP supplied from the terminal 108 is allocated by proportional distribution depending on the relative coding difficulty of each picture. The relative encoding difficulty of the pict_ith picture is calculated from the sum total of the relative encoding difficulty of the pict_ith of the macro-blocks of the picture.

At the first step ST88 in the processing from the next step ST88 to step ST94, the variable mb_i is set to 1 from designating the first macro-block MB in the picture as being a macro-block MB processed by the second path processing in the pict_ith picture.

After this step ST88, the above variable mb_i is incremented by one in each step for processing each macro-block MB in the picture with the second-path processing. This processing from step ST89 up to step ST94 is repeated until the second-path processing for all macro-blocks in the picture comes to a close.

By way of the processing from step ST89 up to step ST94, the volume of allocated bits target_bit_mb of the mb_ith macro-block is calculated first at step ST89 by the following equation (27):

$$target_bit_mb[mb_i]=XA*x_mb\ [mb_i] \tag{27}$$

In the equation (27), XA is a constant parameter in the pict_ith picture calculated by the following equation (28)

$$XA=BT/sum_x_mb \tag{28}$$

In the above equation (28), the variable sum_x_mb is the sum total of the relative complexity degree x_mb of the macro-blocks in the pict_ith picture calculated by the first-path processing. This variable sum_x_mb is found by the following equation (29):

$$sum_x_mb=\Sigma x_[mb_i](mb_i=1\ to\ NMB) \tag{29}$$

At the next step ST90, the quantization scale mQ of the mb_ith macro-block MB is calculated by the following equation (30):

$$mQ[mb_i]=KQ[mb_i]/(KQ*XA*weighu_mb[mb_i]) \tag{30}$$

In the above equation, KR is a coefficient pertinent to the target bit rate, while KQ[mb_i] is a learning parameter which is updated at the subsequently step ST92 from one macro-block MB to another.

At the next step ST91, the DCT coefficients of the mb_ith macro-block MB are quantized and encoded. This enables calculations of the actual volume of generated bits bit_mb [mb_i] in the mb_ith macro-block MB.

At the next step ST92, the learning parameter KQ is updated. As learning parameters, KQ_I, KQ_P and KQ_B are provided for the I-, P- and B-pictures, respectively. These are updated by the equations (31), (32) and (33), respectively:

$$KQ_I[mb_i+1]=KQ_I[1]+BG[mb_1]\cdot BTMB[mb_i] \tag{31}$$

$$KQ_P[mb_i+1]=KQ_P[1]+BG[mb_1]\cdot BTMB[mb_i] \tag{32}$$

$$KQ_B[mb_i+1]=KQ_B[1]+BG[mb_1]\cdot BTMB[mb_i] \tag{33}$$

In the above equations, KQ_I[1], KQ_P[1] and KQ_B [1] are initial values for the first macro-blocks MB of the I-, P- and B-pictures, respectively. On the other hand, BG[mb_i] is a sum total of the volumes of generated encoding bits bit_mb as from the first macro-block MB up to the mb_its macro-block MB of a picture, as indicated in the following equation (34):

$$BG[mb_i]=\Sigma bit_mb[mb_i]\ (I=1\ to\ mb_i) \tag{34}$$

whereas BTMB[mb_i] is a sum total of the volumes of allocated bits target_bit_mb as from the first macro-block MB up to the mb_ith macro-block MB of a picture, as indicated in the following equation (35)

$$BTMB[mb_i]=\Sigma target_bit_mb[i]\ (I=1\ to\ mb_i)$$

At the next step ST93, the address of the macro-block MB is advanced by one, that is, the above variable mb_1 is incremented by one.

At step ST94, it is judged whether or not processing of the last macro-block of the pict_ith picture has come to a close. If it is found at step ST94 that the processing has not come to a close, processing reverts to step ST89 and, if otherwise, processing transfers to step ST95 to increment the coefficient pict_i by one to transfer to processing of the next picture.

Then, at step ST96, averaged values of the learning parameters KQ_I, KP_P and KQ_B of the picture on encoding the I-, P- or B-pictures are substituted for initial values KQ_I[1], KQ_P[1] and KQ_B[1] for the next pictures of the same picture types, respectively. This substitution is by the following equations (36), (37) and (38):

$$KQ_I(1)=(\Sigma KQ_I[i])/NMB\ (I=2\ to\ mb_i+1) \tag{36}$$

$$KQ_P(1)=(\Sigma KQ_P(i))/NMB\ (I=2\ to\ mb_i+1) \tag{37}$$

$$KQ_B(1)=(\Sigma KQ_B(i))/NMB\ (I=2\ to\ mb_i+1) \tag{38}$$

At the next step ST97, it is judged whether or not processing of the last picture of the sequence (with the number of pictures equal to NPICT) has come to a close. If it is found at step ST97 that the processing has not come to a close, processing reverts to step ST87 and, if otherwise, processing transfers to step ST98 to terminate the processing of the second-path bit rate control.

The amount of delay between the above-mentioned first and second paths is preferably not less than 1 GOP. For providing this time delay, the delay circuit 102 of FIG. 5 or the delay circuit 102 of FIG. 9 is used. If all pictures of the

sequence are encoded as I-pictures, one-picture time suffices as the amount of delay between the first and second paths. On the other hand, if the number of the pictures in a sequence NPCT=1, a still picture is encoded as an I-picture, so that one picture suffices as the amount of delay between the first and second paths.

The encoded bitstream, obtained by encoding by the first and second embodiments of the picture signal encoding device, is recorded on a signal recording medium according to the present invention or transmitted over a transmission channel.

FIGS. **5** and **9** show examples of using an optical disc **704** as a signal recording medium for recording or transmission over a transmission channel.

In case of recording on the optical disc **704** in FIGS. **5** or **9**, a data stream composed of an encoded bitstream outputted at the output terminal **106** and the information necessary for subsequent decoding, such as the quantization scale, is added to an error correction code by an error correction encoder (ECC encoder) **701** before being sent to a modulation circuit **702**. The modulation circuit **702** processes the output of the error correction encoder **701** with pre-set modulation, such as so-called 8–14 (eight-to-fourteen modulation or EFM) or 8–16 modulation. By this modulation, the encoded 8-bit data are converted to 14 or 16 bit data for matching the digital signals to transmission characteristics for the optical disc **704**. An output of the modulation circuit **702** is sent to a recording head **703** where it is recorded on the optical disc **704**. Although the optical disc is used as a signal recording medium in the examples of FIGS. **5** and **9**, the recording medium may also be a magnetic disc medium, such as a hard disc or a flexible disc, a tape-shaped recording medium, an IC card or a semiconductor memory, such as various memory devices. As an optical disc, a variety of optical discs, such as a phase transition type optical disc, an organic dye type optical disc, an optical disc for recording by UV laser light beam or an optical disc having a multi-layer recording film, may be used besides the disc for recording by physically forming pits, or a magneto-optical disc.

For transmission over a transmission channel, the above-mentioned data string is added to with an error correction code by an error correction encoder **711** and thence transmitted over the transmission channel via interfacing circuit **712** and a terminal **713**. The transmission channel also includes electric waves or light in addition to the usual transmission cable..

For controlling the quantization scale for quantizing data of a macro-block MB in the above-described picture signal encoding method and apparatus of the present invention, a volume of bits allocated to a picture is received, calculations are then made of the relative complexity degree of all macro-blocks MB of the picture, and the quantization scale of the macro-blocks is calculated taking into account the volume of allocated bits necessary for each macro-block of the picture.

Thus, if the picture pattern is not uniform, as when the contents of the upper half and the lower half of a picture differ from each other such that the upper half picture is simple in picture pattern and the lower half picture is complex in picture pattern, the volume of bits necessary for the upper half picture and that necessary for the lower half picture can be adaptively allocated for calculating optimum quantization scale, thus enabling the picture to be encoded with higher picture quality than is possible with the conventional method.

Moreover, in calculating the complexity degree of all macro-blocks of a picture in advance as described above, the relative complexity degree for each macro-block MB of a picture is calculated from the relative coding difficulty and the weighting coefficients representing the variable visibility degree of picture quality deterioration. Specifically, the relative coding difficulty of the macro-block MB is calculated using the volume of bits generated on encoding the macro-block with a fixed quantization scale, the volume of prediction residual signal on detecting the motion vector of the macro-block MB or the difference residual volume from the mean value, of the macro-block MB, while the weighting coefficients representing the variable visibility degree of picture quality deterioration of the macro-block MB is calculated using at least one of lightness, red level, amount of motion and the position of the macro-block MB in the picture, in addition to flatness of the luminance signals. This enables encoding with less visibility of the deterioration in picture quality than is possible with the conventional method.

Also, in calculating the quantization scale of the macro-block MB taking into account the amount of allocated bits required for each macro-block MB of each picture, the volume of bits allocated to each macro-block is calculated so that the allocated bit volume will be proportionate to the variable complexity degree of each macro-block relative to the complexity degree of the entire picture. This enables extremely flexible designation of the weighting coefficients representing the variable visibility degree of picture contra-distinction from the conventional system, there is no necessity for normalization so that the expected value of the weighting coefficients for one picture will be equal to 1.

In addition, in the picture signal encoding method and apparatus embodying the invention, there is presented no such problem that, if the quantization scale mQ indicated by reference numerals entered in each macro-block MB in FIG. **17** has been calculated, and the weighting coefficients of macro-blocks shown shaded in FIG. **17** are increased with a view to reducing the quantization scale of the shaded macro-blocks MB, only the values of the quantization scale calculated for the macro-blocks MB downstream of the shaded macro-blocks are increased, as in the case shown in FIG. **4**. This assures stabilized bit rate control as compared to that achieved with the above-mentioned prior-art method.

Thus, when encoding a picture corresponding to moving picture signals by dividing the picture into plural domains (MB) and encoding the picture from domain to domain, the picture quality can be rendered substantially uniform even if the picture pattern is not uniform by calculating the relative coding difficulty from one domain (MB) to another and the weighting coefficients representing the visibility degree of picture quality deterioration from one domain to another, calculating the complexity degree from the relative coding difficulty and the weighting coefficients from one domain to another and by calculating the quantization scale for encoding each domain using the allocated bit volumes for picture encoding and the above-mentioned complexity degree. In addition, the volume of bits occupying a virtual buffer can be stabilized to render picture quality deterioration less visible while assuring stabilized rate control.

What is claimed is:

1. A method for encoding picture signals in which moving picture signals are divided into plural macroblocks for encoding from one macroblock to another, comprising the steps of:

calculating relative coding difficulty from macroblock to macroblock;

calculating for each macroblock weighting coefficients representing a respective degree of visibility of picture quality deterioration;

calculating a complexity degree from macroblock to macroblock, based on the relative coding difficulty and the weighting coefficients; and

calculating the quantization scale for encoding for the macroblocks based on the complexity degree and allocated bit volumes for encoding the macroblocks.

2. The method as claimed in claim **1** wherein the allocated bit volumes for encoding the macroblocks are calculated based on the complexity degree of the macroblocks relative to the complexity degree of the entire picture.

3. The method as claimed in claim **1** wherein said relative coding difficulty is calculated based on the volume of codes generated on encoding each macroblock with a fixed quantization scale.

4. The method as claimed in claim **1** wherein said relative coding difficulty is calculated based on the volume of predicted remainder signals at the time of detecting the motion vector of each macroblock.

5. The method as claimed in claim **1** wherein said relative coding difficulty is calculated based on the difference residual volume from a mean value of each macroblock.

6. The method as claimed in claim **1** wherein said weighting coefficients are calculated based on the lightness and flatness of luminance signals of said moving picture.

7. The method as claimed in claim **1** wherein said weighting coefficients are calculated based on the redness and flatness of luminance signals of said moving picture.

8. The method as claimed in claim **1** wherein said weighting coefficients are calculated based on the flatness and the amount of motion of luminance signals of said moving picture.

9. The method as claimed in claim **1** wherein said weighting coefficients are calculated based on the flatness of the luminance signals of the moving picture signals and the position of each macroblock in the picture.

10. The method as claimed in claim **1** wherein said weighting coefficients are calculated based on the combination of two or more of the lightness, redness, amount of motion and the position of each macroblock in the picture, in addition to the flatness of the luminance signals of the moving picture.

11. The method as claimed in claim **1** further comprising the step of:

encoding the moving picture signals based on said quantization scale for generating an encoded data string and transmitting the resulting encoded data string.

12. The method as claimed in claim **1** further comprising the step of:

encoding the moving picture signals based on said quantization scale for generating an encoded data string and recording the resulting encoded data string on a recording medium.

13. An apparatus for encoding picture signals in which a picture constituting moving picture signals is divided into plural macroblocks for encoding from one macroblock to another, comprising:

means for calculating relative coding difficulty from macroblock to macroblock;

means for calculating for each macroblock weighting coefficients representing a respective degree of visibility of picture quality deterioration; and

means for calculating a complexity degree from macroblock to macroblock, based on the relative coding difficulty and the weighting coefficients, and calculating the quantization scale for encoding for the macroblocks based on the complexity degree and allocated bit volumes for encoding the domains.

14. The apparatus as claimed in claim **13** wherein said quantization scale calculating means calculates the allocated bit volumes for the macroblocks based on the complexity degree of the macroblocks relative to the complexity degree of the entire picture.

15. The apparatus as claimed in claim **13** wherein said relative coding difficulty calculating means calculate the relative coding difficulty based on the volume of codes generated on encoding each macroblock with a fixed quantization scale.

16. The apparatus as claimed in claim **13** wherein said relative coding difficulty calculating means calculates said relative coding difficulty based on the volume of predicted remainder signals at the time of detecting the motion vector of each macroblock.

17. The apparatus as claimed in claim **13** wherein said relative coding difficulty calculating means calculates said relative coding difficulty based on the difference residual volume from a mean value of each macroblock.

18. The apparatus as claimed in claim **13** wherein said weighting coefficient calculating means calculates the weighting coefficients based on the lightness and flatness of luminance signals of said moving picture.

19. The apparatus as claimed in claim **13** wherein said weighting coefficient calculating means calculates the weighting coefficients are calculated based on the redness and flatness of luminance signals of said moving picture.

20. The apparatus as claimed in claim **13** wherein said weighting coefficient calculating means calculates the weighting coefficients based on the flatness and the amount of motion luminance signals of said moving picture.

21. The apparatus as claimed in claim **13** wherein said weighting coefficient calculating means calculates the weighting coefficients based on the flatness of the luminance signals of the moving picture signals and the position of each macroblock in the picture.

22. The apparatus as claimed in claim **13** wherein said weighting coefficient calculating means calculates the weighting coefficients based on the combination of two or more of the lightness, redness, amount of motion and the position of each macroblock in the picture, in addition to the flatness of the luminance signals of the moving picture.

23. The apparatus as claimed in claim **13** further comprising:

transmission means for transmitting the resulting encoded data string.

24. The apparatus as claimed in claim **13** further comprising:

recording means for recording an encoded data string, obtained on encoding said moving picture signals based on the quantization scale, on a recording medium.

25. A recording medium having recorded thereon an encoded data string obtained by calculating, for each plural macroblocks into which is divided a picture making up moving picture signals, the relative coding difficulty and weighting coefficients representing the visibility degree of picture quality deterioration;

calculating the complexity degree from said relative coding difficulty and the weighting coefficients;

calculating the quantization scale of encoding for each macroblock based on the volume of allocated bits for encoding each macroblock and complexity degree; and

encoding each macroblock based on said quantization scale.

26. The recording medium as claimed in claim **25** wherein the allocated bit volumes for encoding the macroblocks are

calculated based on the complexity degree of the macroblocks relative to the complexity degree of the entire picture.

27. The recording medium as claimed in claim 25 wherein said relative coding difficulty is calculated based on the volume of codes generated on encoding each macroblock with a fixed quantization scale.

28. The recording medium as claimed in claim 25 wherein said relative coding difficulty is calculated based on the volume of predicted remainder signals at the time of detecting the motion vector of each macroblock.

29. The recording medium as claimed in claim 25 wherein said relative coding difficulty is calculated based on the difference residual volume from a mean value of each macroblock.

30. The recording medium as claimed in claim 25 wherein said weighting coefficients are calculated based on the lightness and flatness of luminance signals of said moving picture.

31. The recording medium as claimed in claim 25 wherein said weighting coefficients are calculated based on the redness and flatness of luminance signals of said moving picture.

32. The recording medium as claimed in claim 25 wherein said weighting coefficients are calculated based on the flatness and the amount of motion of luminance signals of said moving picture.

33. The recording medium as claimed in claim 25 wherein said weighting coefficients are calculated based on the flatness of the luminance signals of the moving picture signals and the position of each macroblock in the picture.

34. The recording medium as claimed in claim 25 wherein said weighting coefficients are calculated based on the combination of two or more of the lightness, redness, amount of motion and the position of each macroblock in the picture, in addition to the flatness of the luminance signals of the moving picture.

35. The recording medium as claimed in claim 25 further comprising the step of:

encoding the moving picture signals based on said quantization scale for generating an encoded data string and transmitting the resulting encoded data string.

36. The recording medium as claimed in claim 25 further comprising the step of:

encoding the moving picture signals based on said quantization scale for generating an encoded data string and recording the resulting encoded data string on a recording medium.

37. A transmission channel having transmitted thereover an encoded data string obtained by calculating, for each plural macroblocks into which is divided a picture taking up moving picture signals, the relative coding difficulty and weighting coefficients representing the visibility degree of picture quality deterioration;

calculating the complexity degree from said relative coding difficulty and the weighting coefficients;

calculating the quantization scale of encoding for each macroblock based on the volume of allocated bits for encoding each macroblock and complexity degree; and

encoding each macroblock based on said quantization scale.

38. The transmission channel as claimed in claim 37 wherein the allocated bit volumes for encoding the macroblocks are calculated based on the complexity degree of the macroblocks relative to the complexity degree of the entire picture.

39. The transmission channel as claimed in claim 37 wherein said relative coding difficulty is calculated based on the volume of codes generated on encoding each macroblock with a fixed quantization scale.

40. The transmission channel as claimed in claim 37 wherein said relative coding difficulty is calculated based on the volume of predicted remainder signals at the time of detecting the motion vector of each macroblock.

41. The transmission channel as claimed in claim 37 wherein said relative coding difficulty is calculated based on the difference residual volume from a mean value of each macroblock.

42. The transmission channel as claimed in claim 37 wherein said weighting coefficients are calculated based on the lightness and flatness of luminance signals of said moving picture.

43. The transmission channel as claimed in claim 37 wherein said weighting coefficients are calculated based on the redness and flatness of luminance signals of said moving picture.

44. The transmission channel as claimed in claim 37 wherein said weighting coefficients are calculated based on the flatness and the amount of motion of luminance signals of said moving picture.

45. The transmission channel as claimed in claim 37 wherein said weighting coefficients are calculated based on the flatness of the luminance signals of the moving picture signals and the position of each macroblock in the picture.

46. The transmission channel as claimed in claim 37 wherein said weighting coefficients are calculated based on the combination of two or more of the lightness, redness, amount of motion and the position of each macroblock in the picture, in addition to the flatness of the luminance signals of the moving picture.

47. The transmission channel as claimed in claim 37 further comprising the step of:

encoding the moving picture signals based on said quantization scale for generating an encoded data string and transmitting the resulting encoded data string.

48. The transmission channel as claimed in claim 37 further comprising the step of:

encoding the moving picture signals based on said quantization scale for generating an encoded data string and recording the resulting encoded data string on a recording medium.

49. The transmission channel as claimed in claim 37, wherein the transmission channel is electric waves.

50. The transmission channel as claimed in claim 37, wherein the transmission channel is light.

51. The transmission channel as claimed in claim 37, wherein the transmission channel is a transmission cable.

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